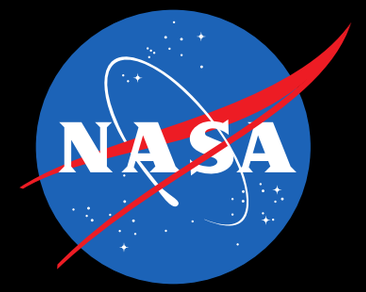
National Aeronautics and
Space Administration



Closing Magmatic Conduits: Constraints from Geodetic Observations and Dynamical Models

Alberto Roman, Marco Bagnardi and Paul Lundgren
Jet Propulsion Laboratory, California Institute of Technology

Progress in monitoring volcanic eruptions

- Understanding how volcanic eruptions proceed is critical for risk assessment and mitigation

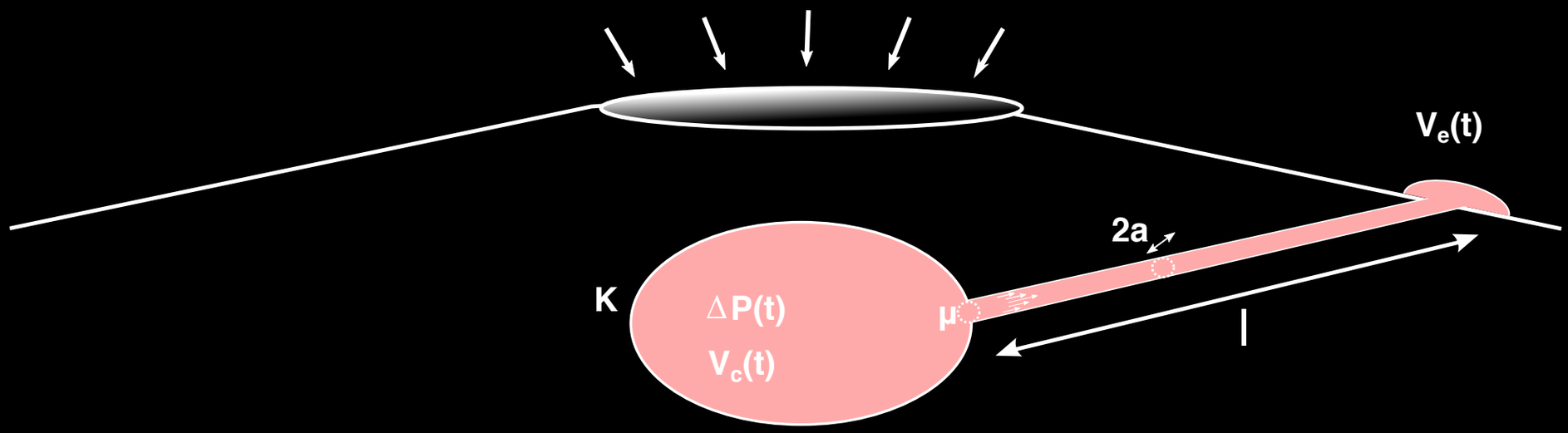
- Dynamical models capturing the physics of magma transport are becoming more and more complex and accurate

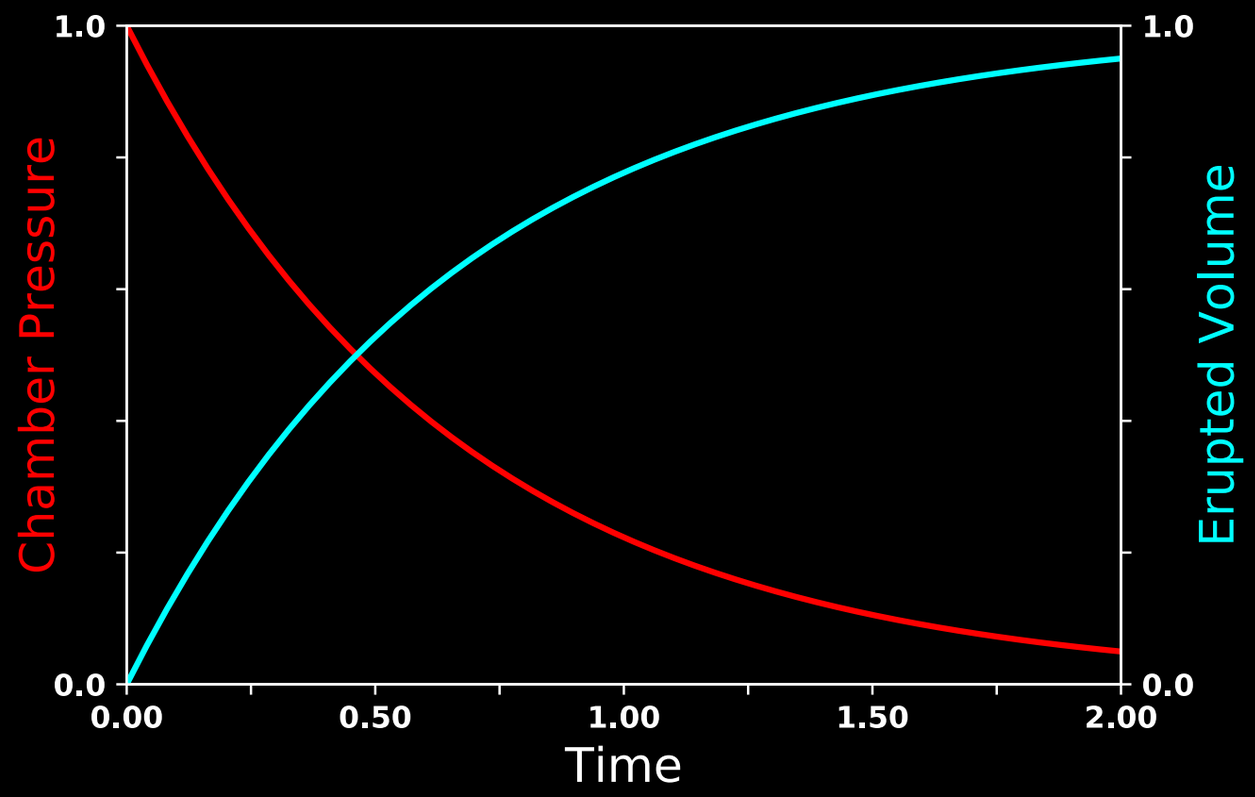
- Geodetic time-series (GNSS and InSAR) are becoming longer, and with higher spatial and temporal resolution. They provide a critical tool to track magma movements in the crust and to monitor eruptions

- The integration of geodetic data-set with dynamical models will provide a comprehensive framework to understand volcanic unrest

Simple physical models

Deformation





Wadge, 1981
Anderson and Segall, 2011

However…

- Magmatic conduits are kept open by a magmatic overpressure
- At depth, the amount of opening is governed by the elastic behaviour of the country rocks
- In the shallow part of the plumbing system a part of the conduit may behave inelastically
- The amount of the overpressure depends on the overpressure at the source, which is time-deependent
- Progessive closing imples reduction of the flux (negative feedback)
- BUT….. DO WE HAVE ANY EVIDENCE OF THIS??????

The Sierra Negra Eruption 2018

Image: Lansat-7, SRTM, GEBCO_08

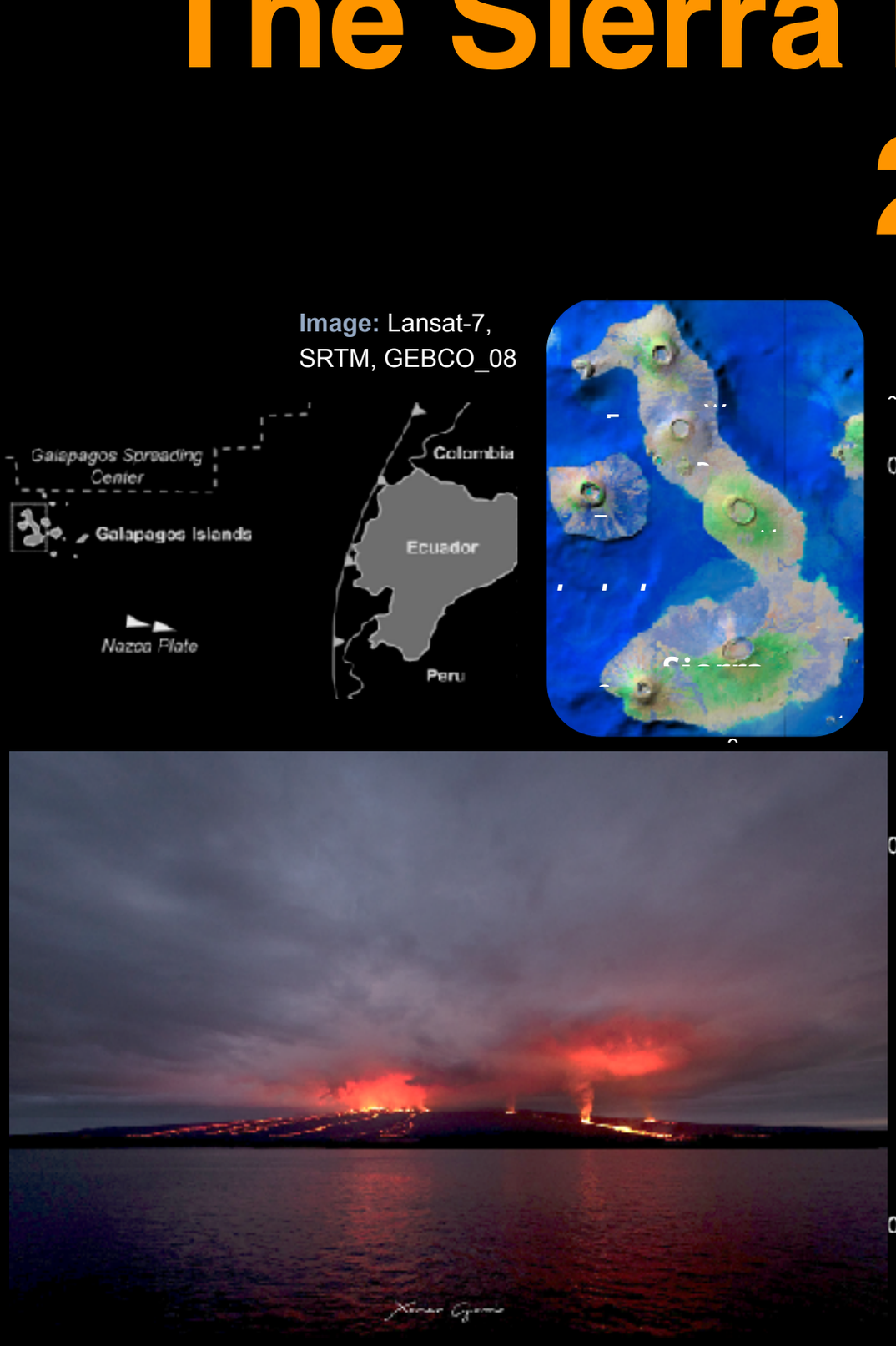
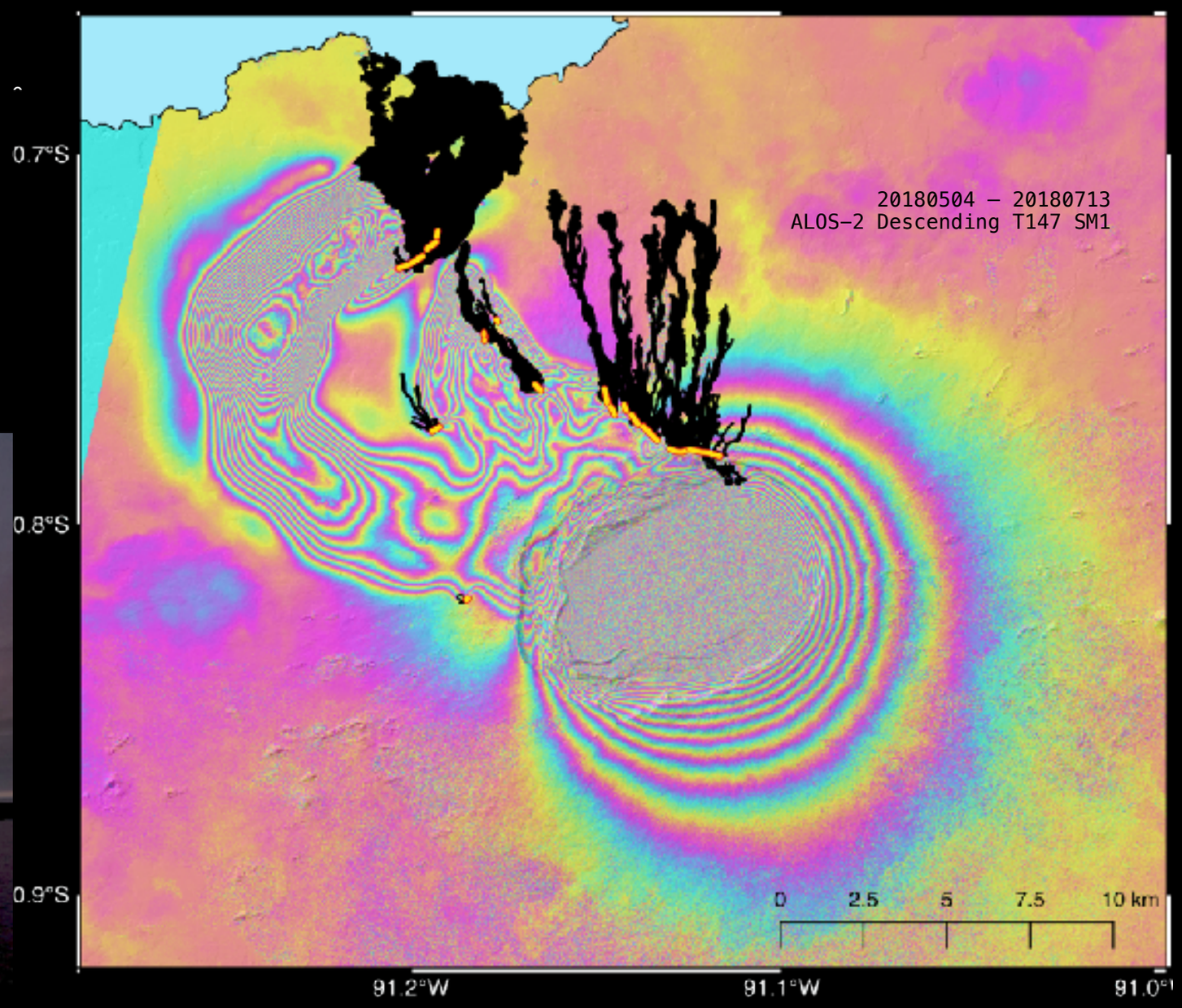


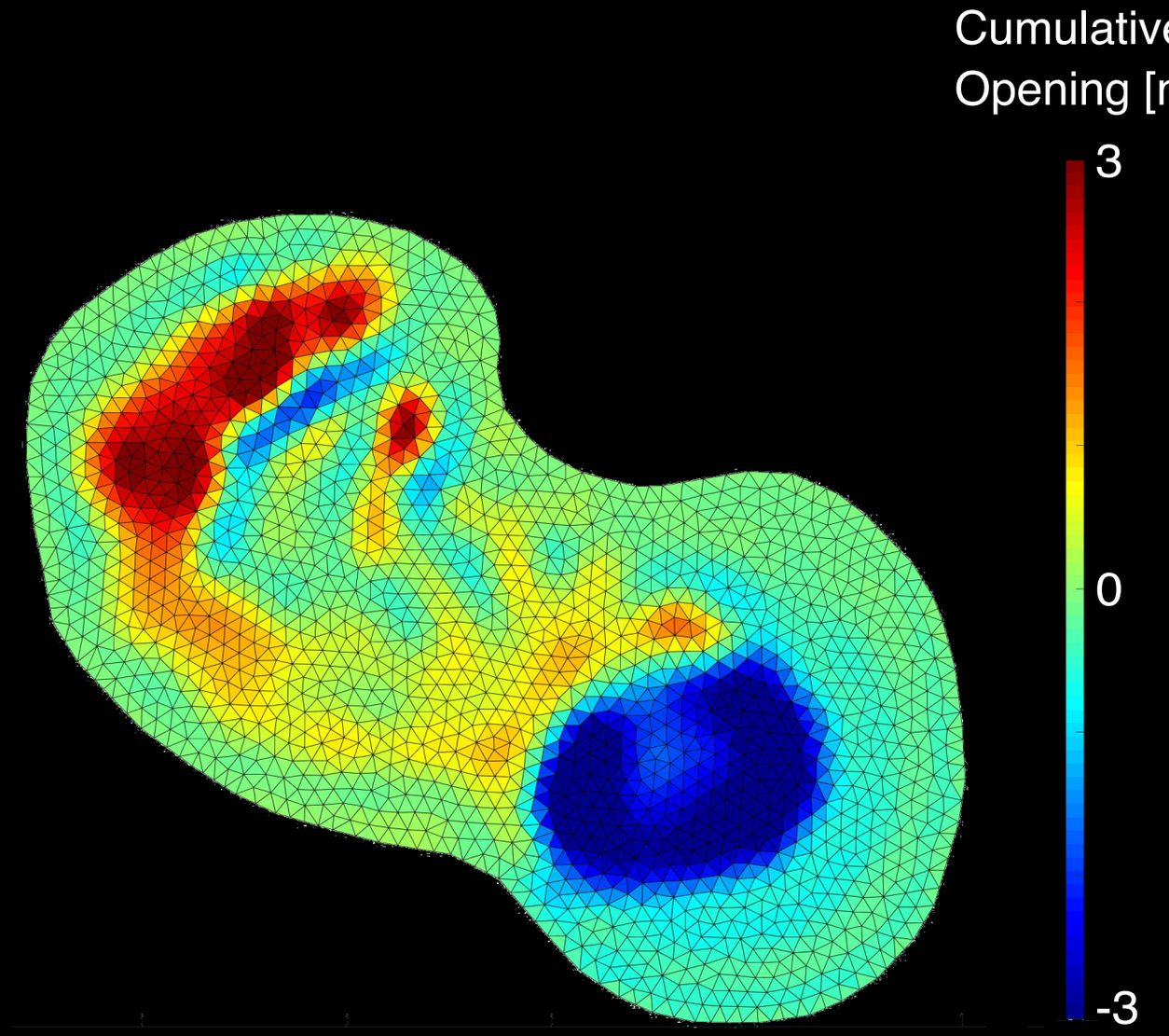
Photo by Parque National Galápagos – Xavier García.

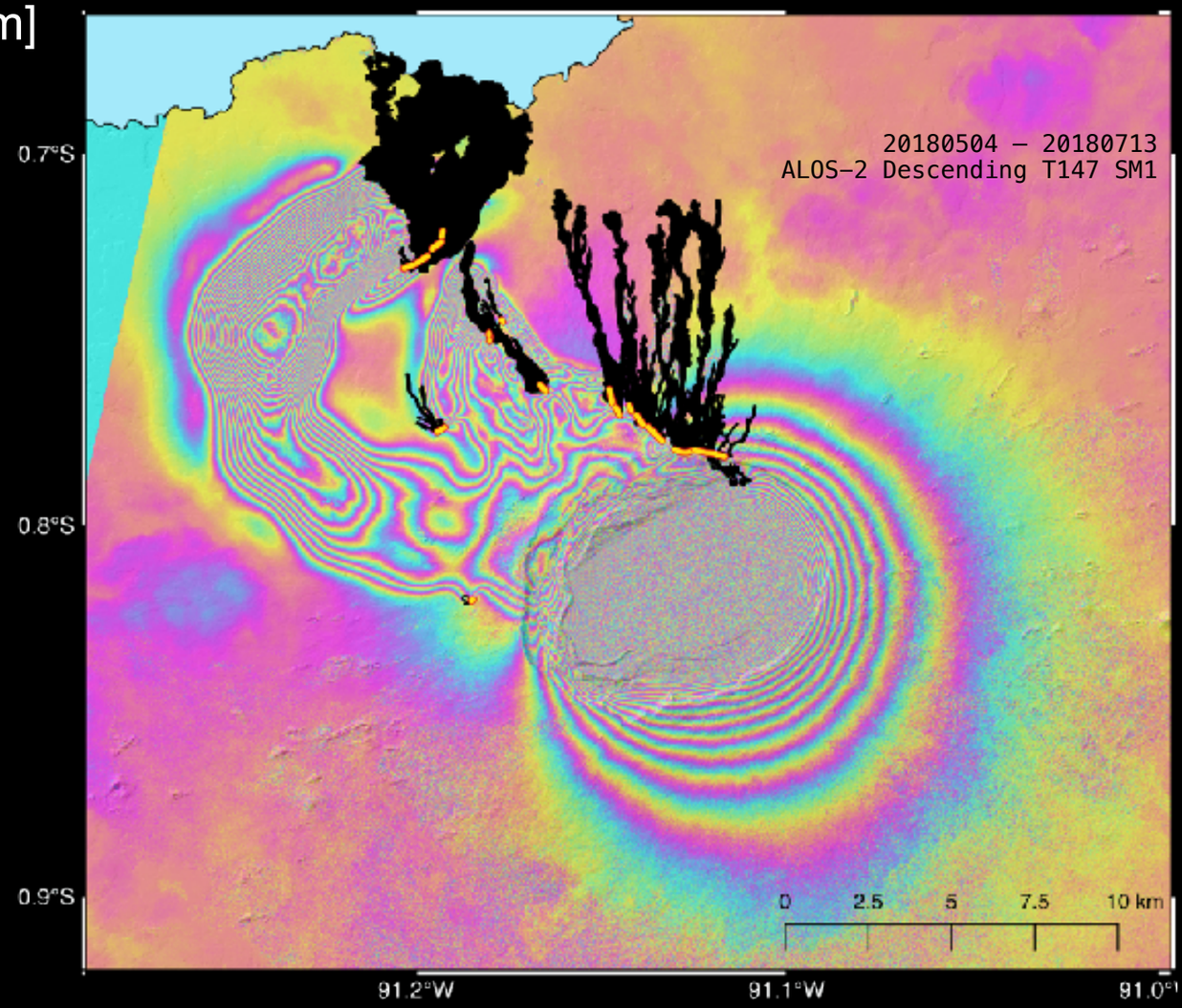
Taken on 06/26/2018 at 18:25 LT, 00:25 UTC
(5 hrs after eruption onset, 7 hrs after seismic swarm)



ALOS-2 data: ! ? 2018 Japan Aerospace Exploration Agency (JAXA)

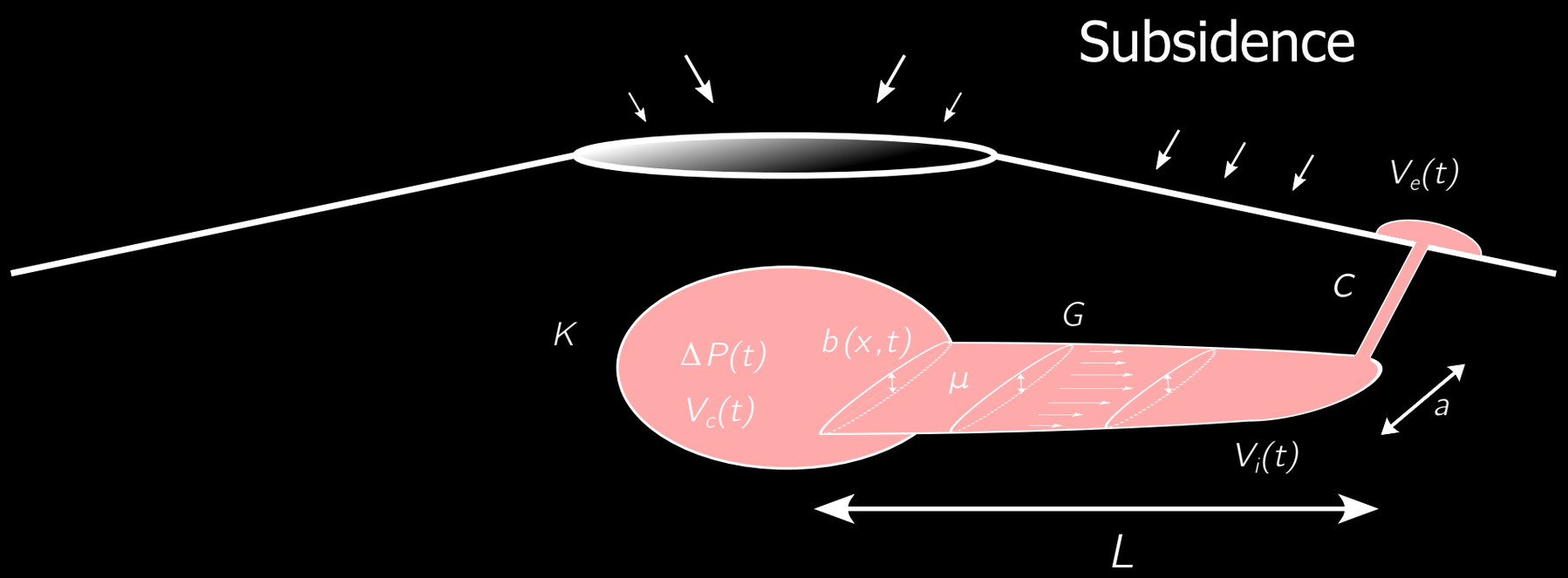
The Sierra Negra Eruption 2018





ALOS-2 data: 2018 Japan Aerospace Exploration Agency (JAXA)

Model



Governing equations

$$\frac{\partial b}{\partial t} = \frac{\partial^2 b^4}{\partial x^2}$$

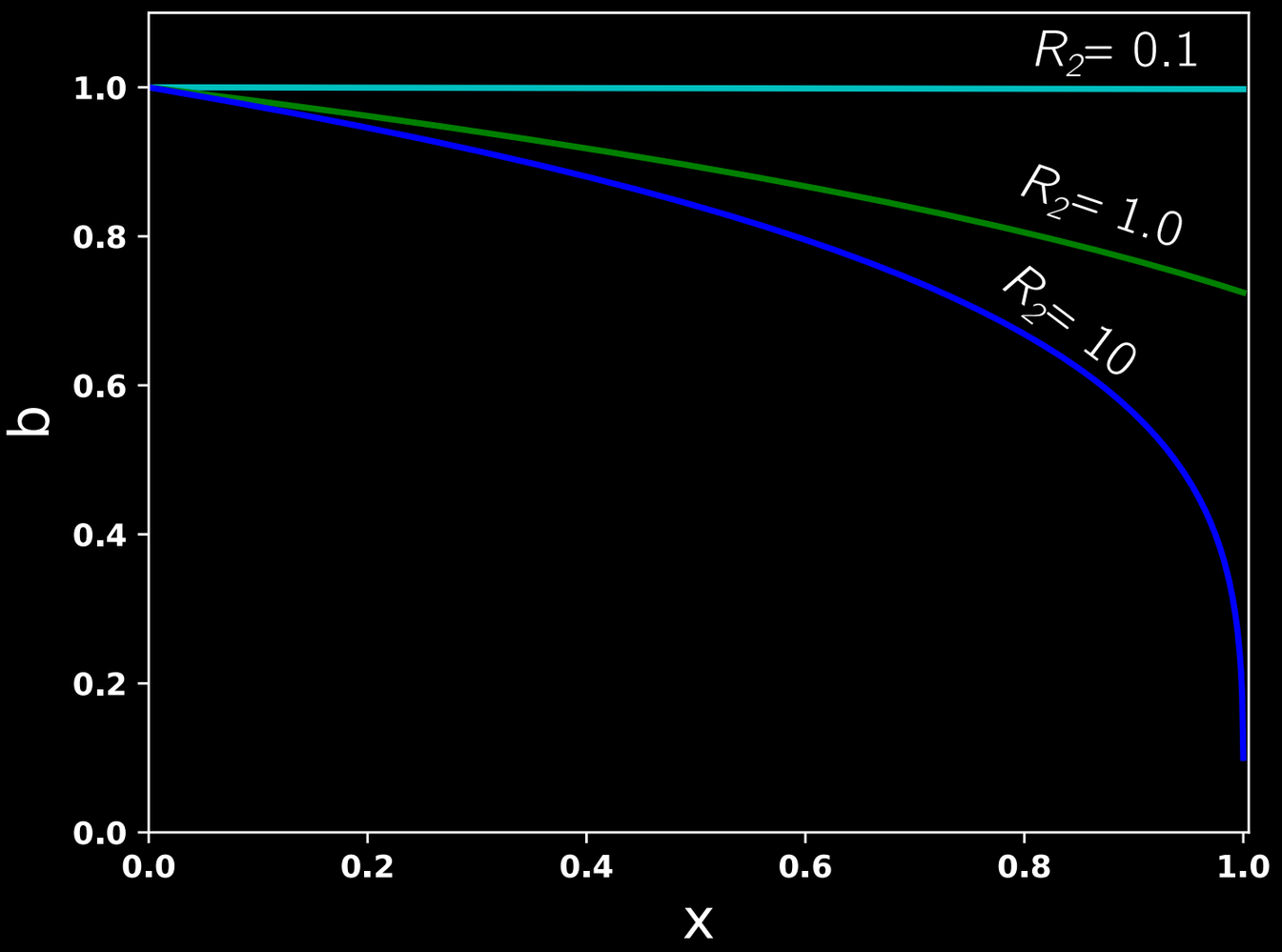
$$q(x=1,t) = -\pi R_2 b_{x=1}$$

$$\frac{\partial b}{\partial t}_{x=0} = -\pi R_3 \frac{\partial b^4}{\partial z}_{x=0}$$

$$R_2 = \frac{4G^3 H c^3}{(1-\nu)a^3 \Delta P^3 L} = 4\frac{c^3}{b^{*3}}\frac{H}{L}$$

$$R_3 = \frac{a^2(1-\nu)\Delta P H K}{V_0 G^2}$$

Steady-state conditions



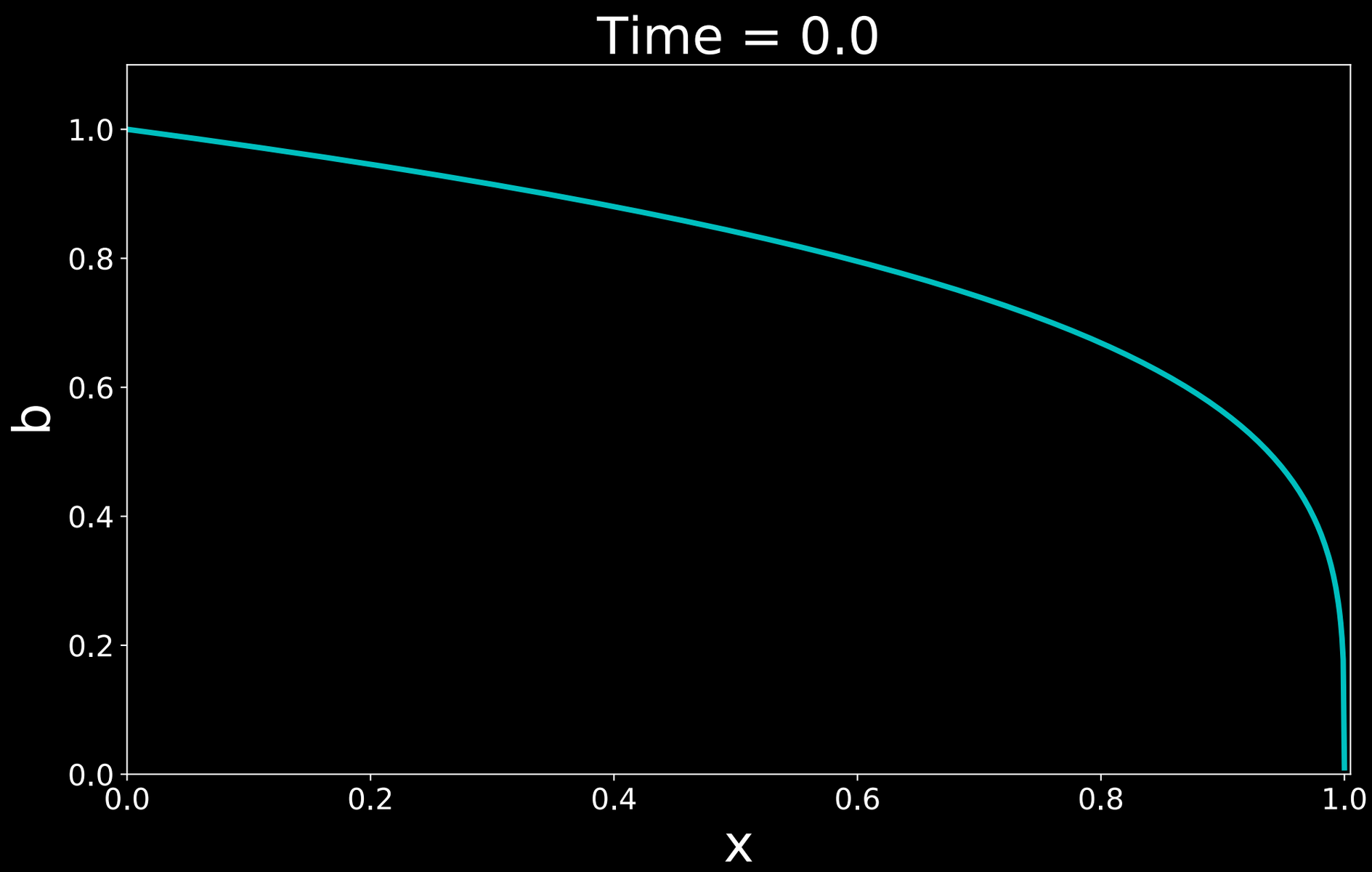
$$R_2 = \frac{4G^3Hc^3}{(1-\nu)a^3\Delta P^3 L} = 4\frac{c^3}{b^{*3}}\frac{H}{L}$$

Small R_2 number correspond to cases in which most of the pressure is lost in the inelastic part of the conduit. The available pressure to deform country rocks in the elastic conduit is approximately constant

At Sierra Negra, propagation switch from horizontal to vertical in the last hundreds of meters (compared to a total length of ~20 km)

$R_2 << 1$

Deflating Reservoir



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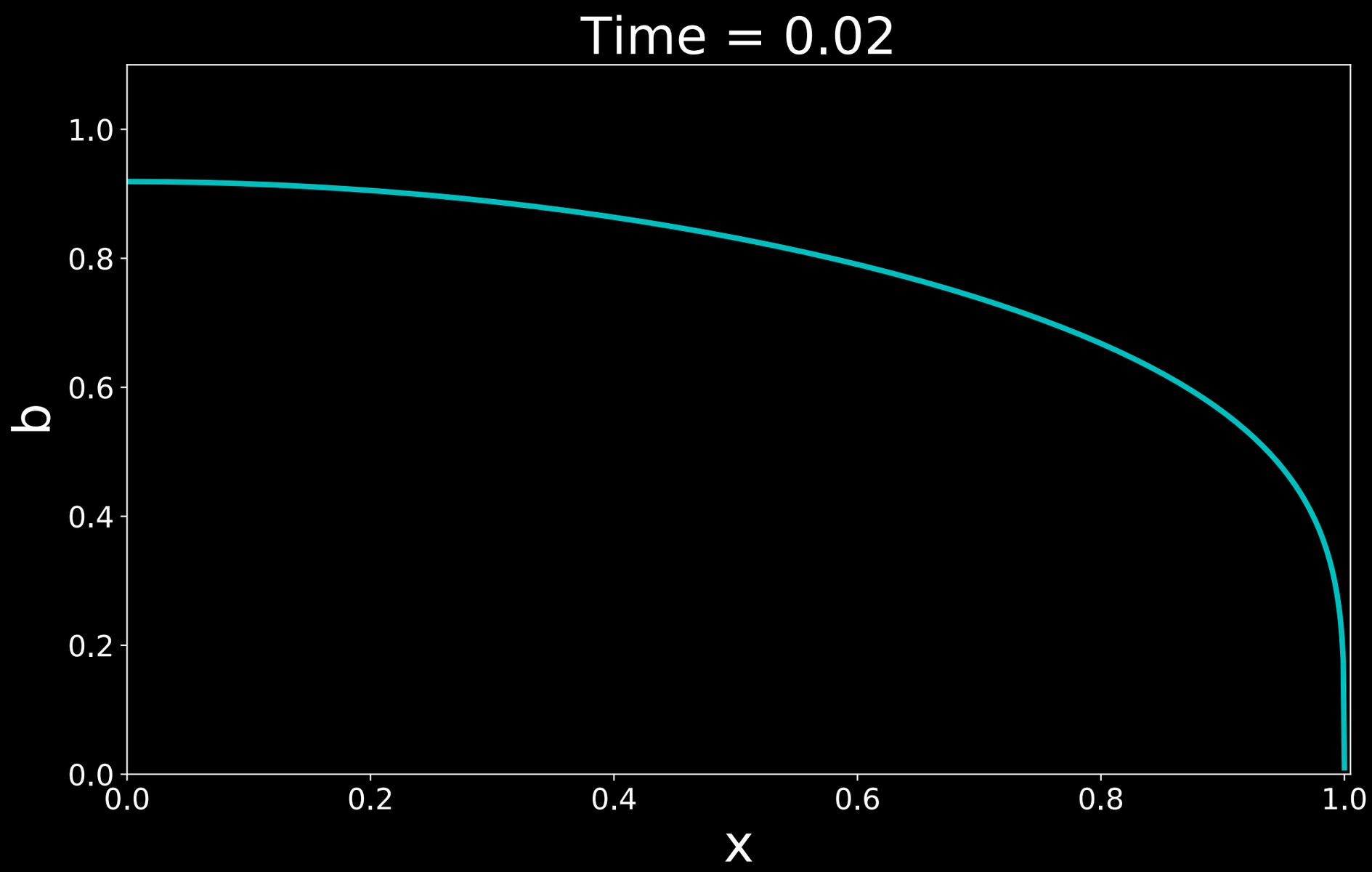

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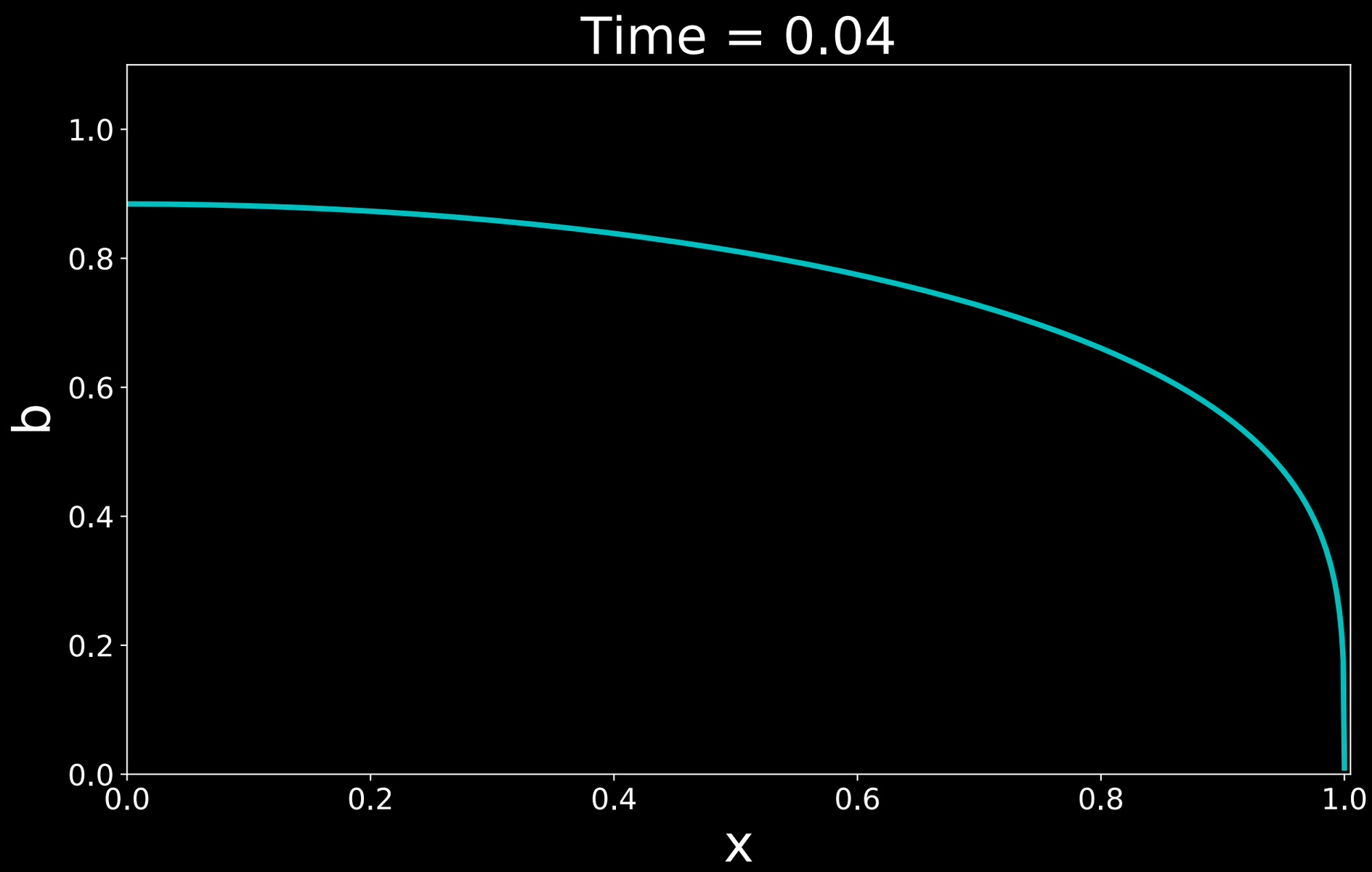

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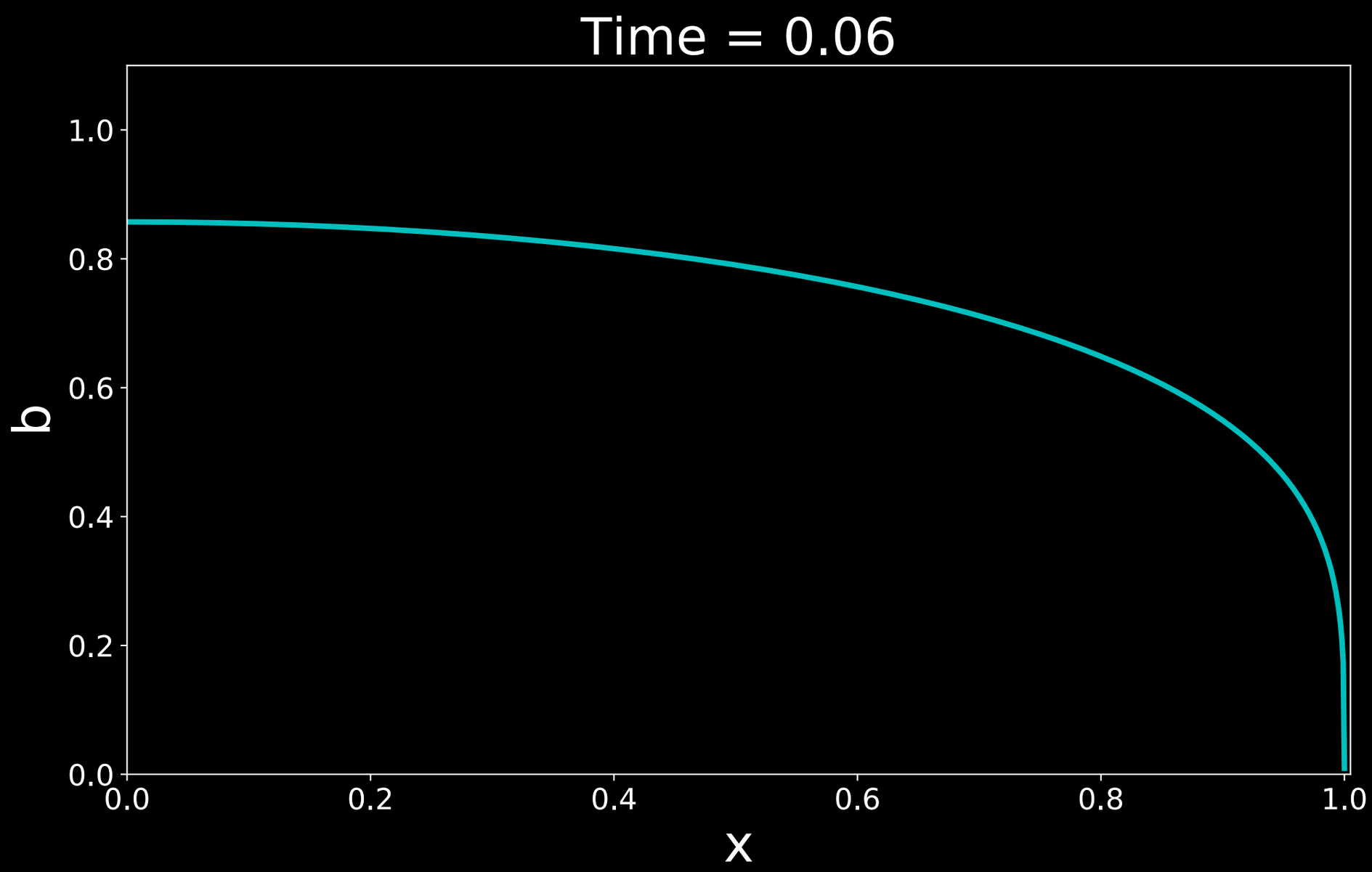

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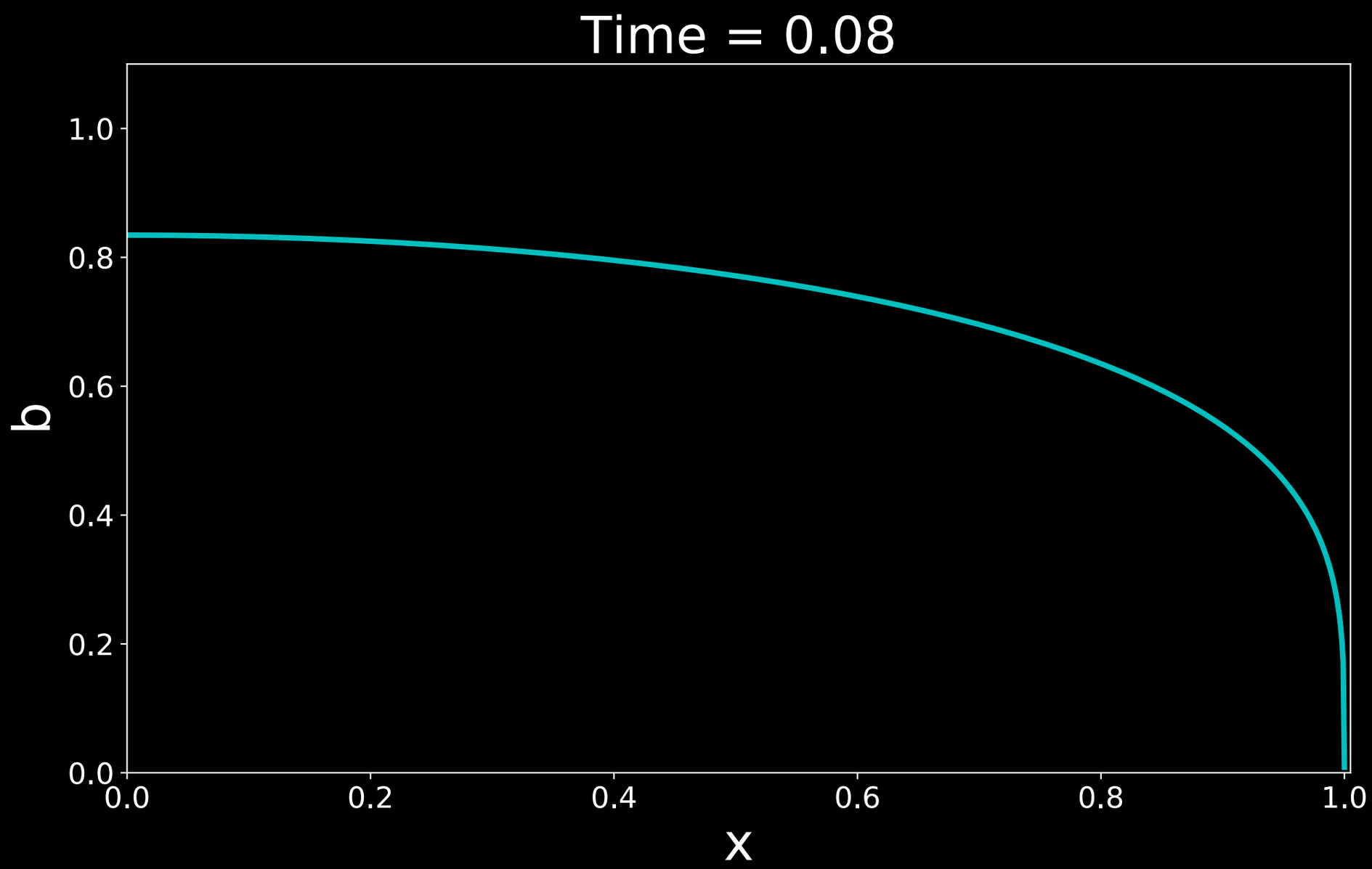

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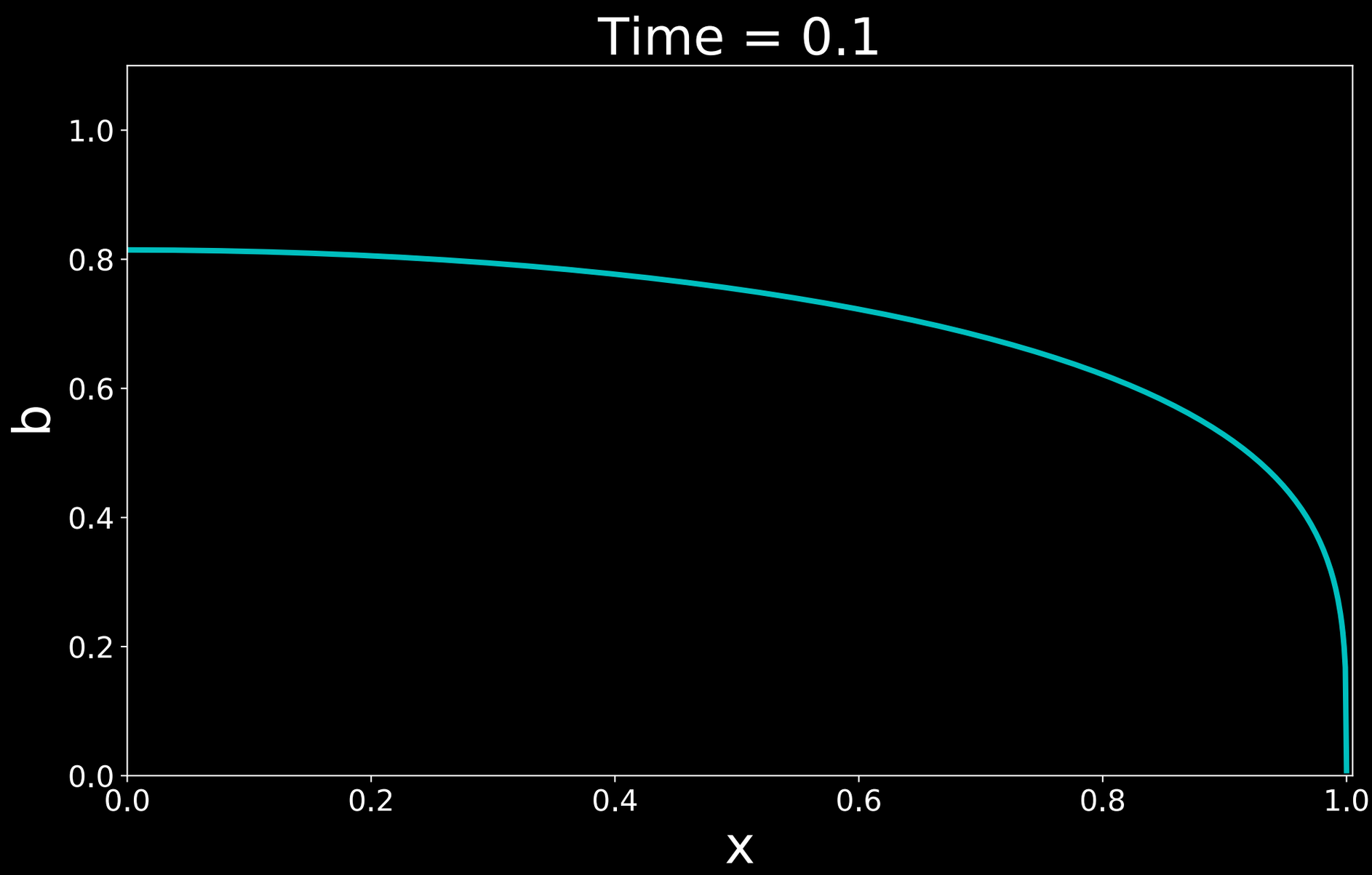

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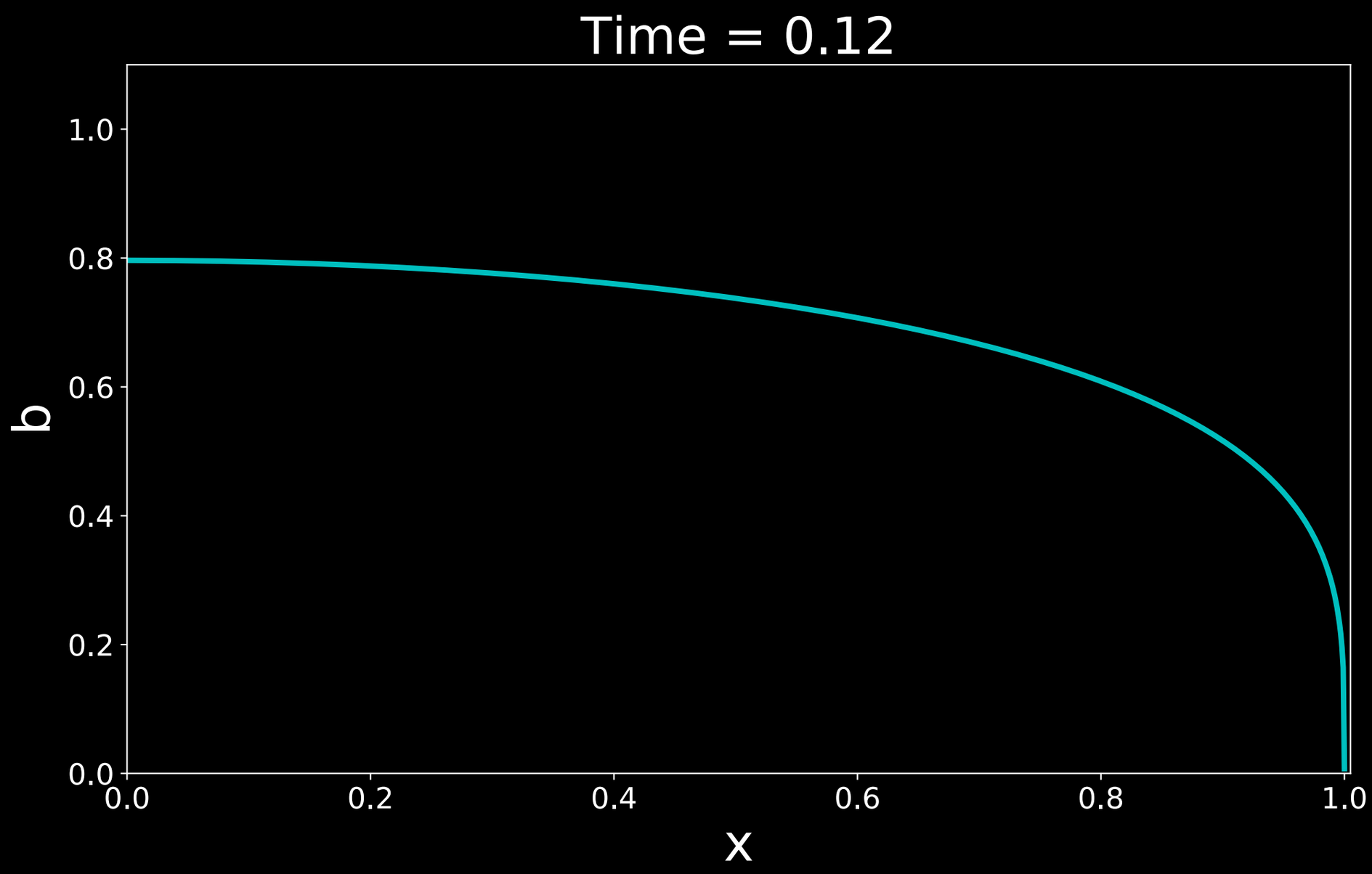

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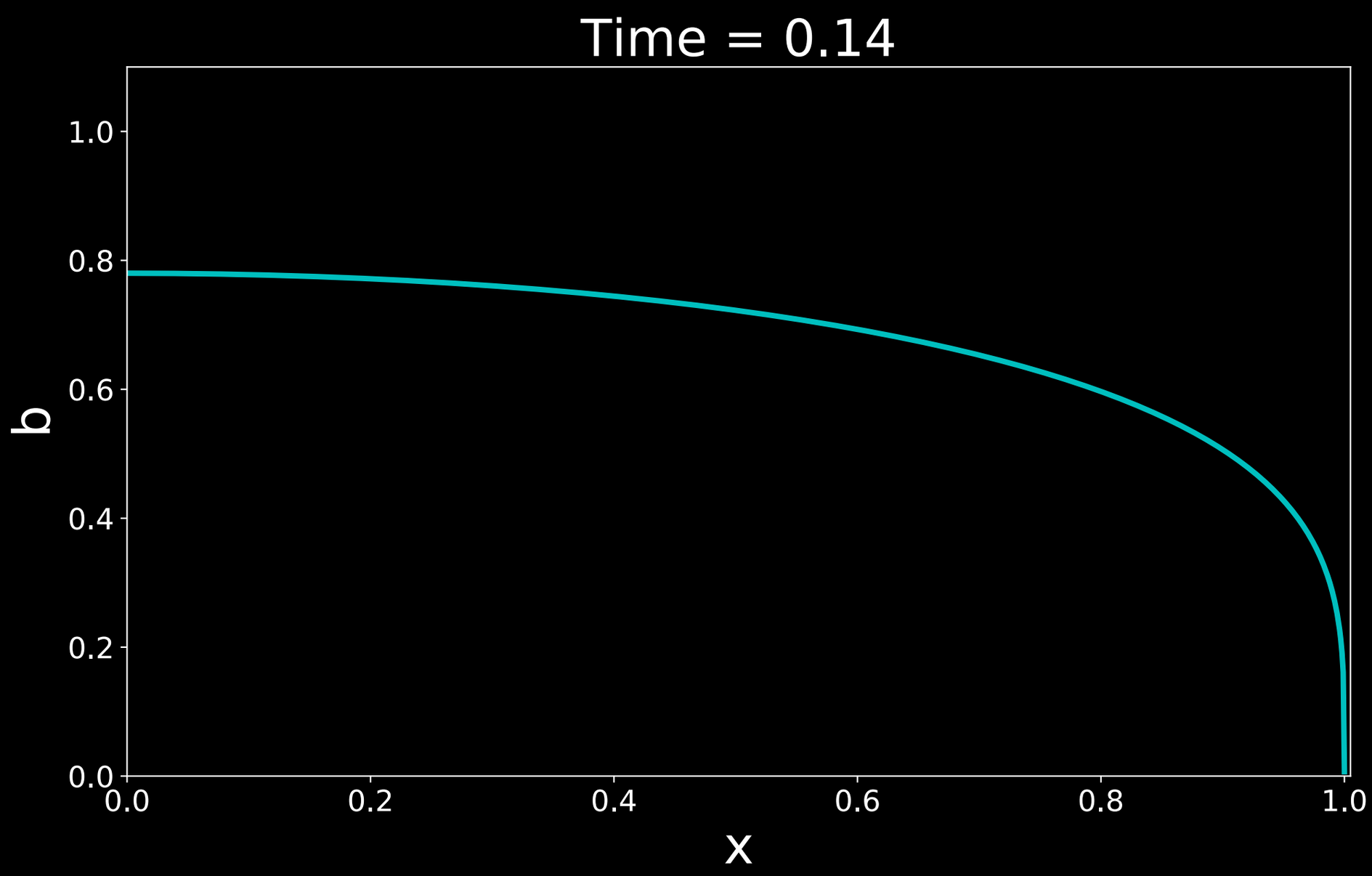

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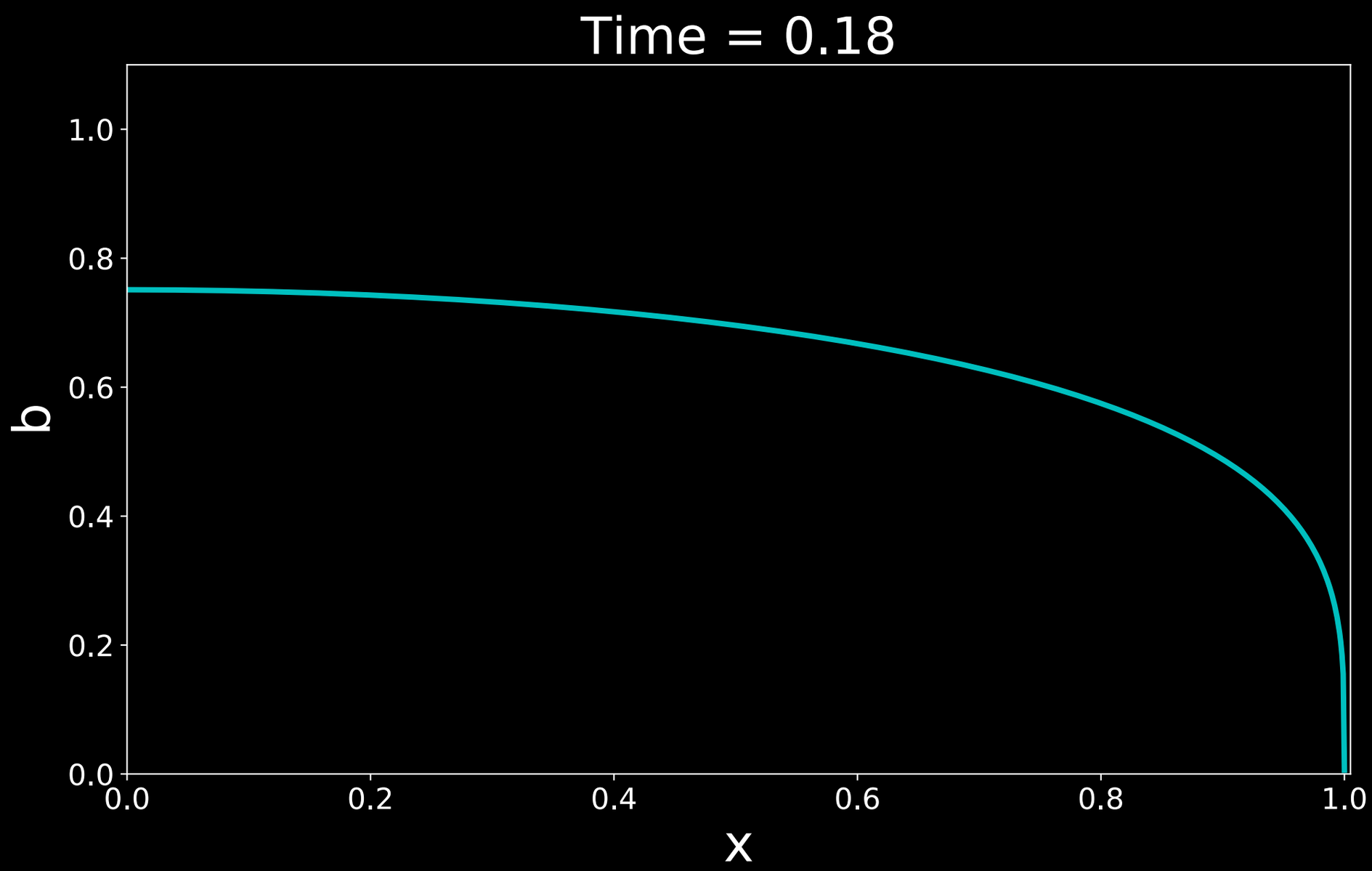

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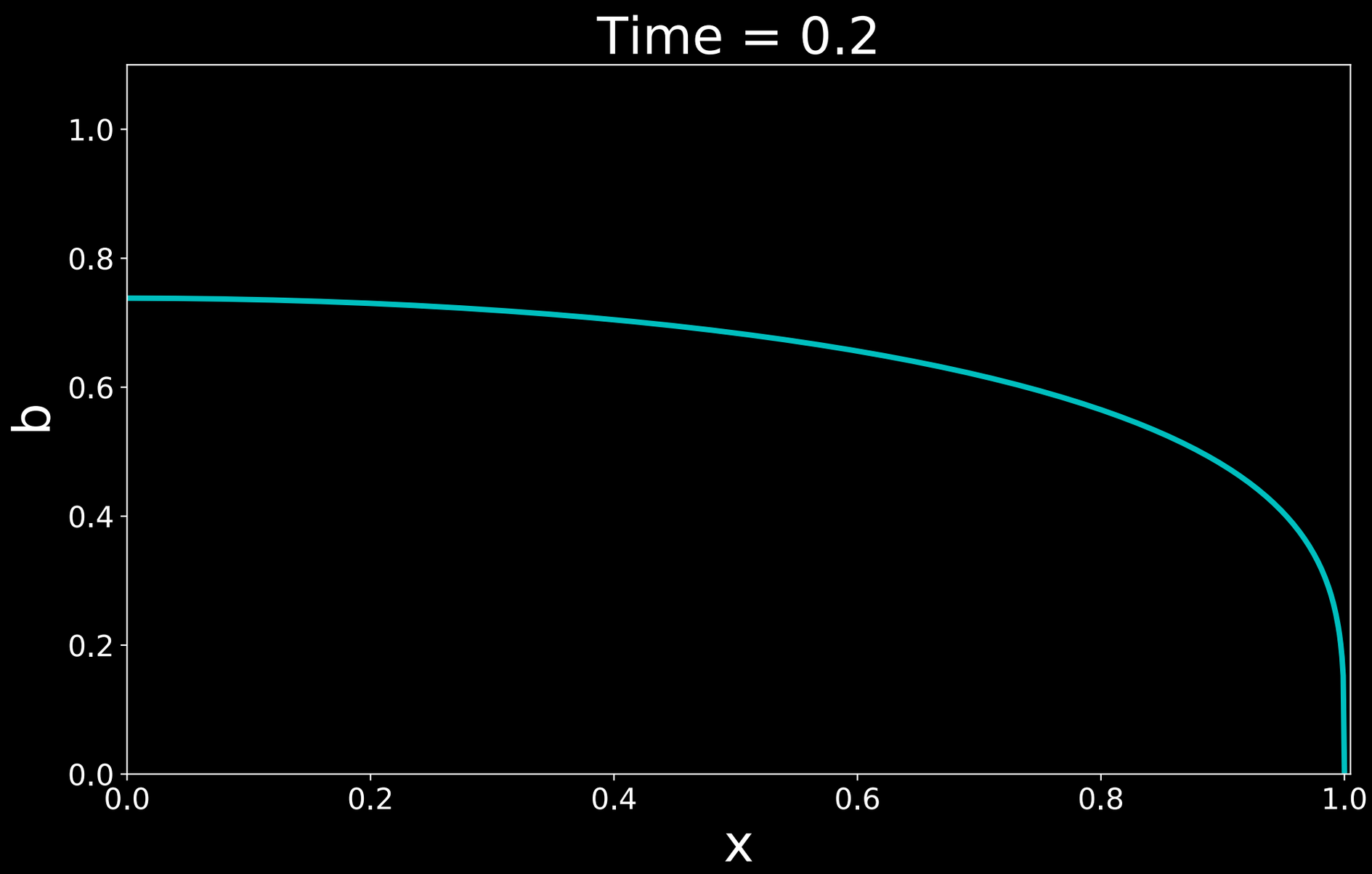

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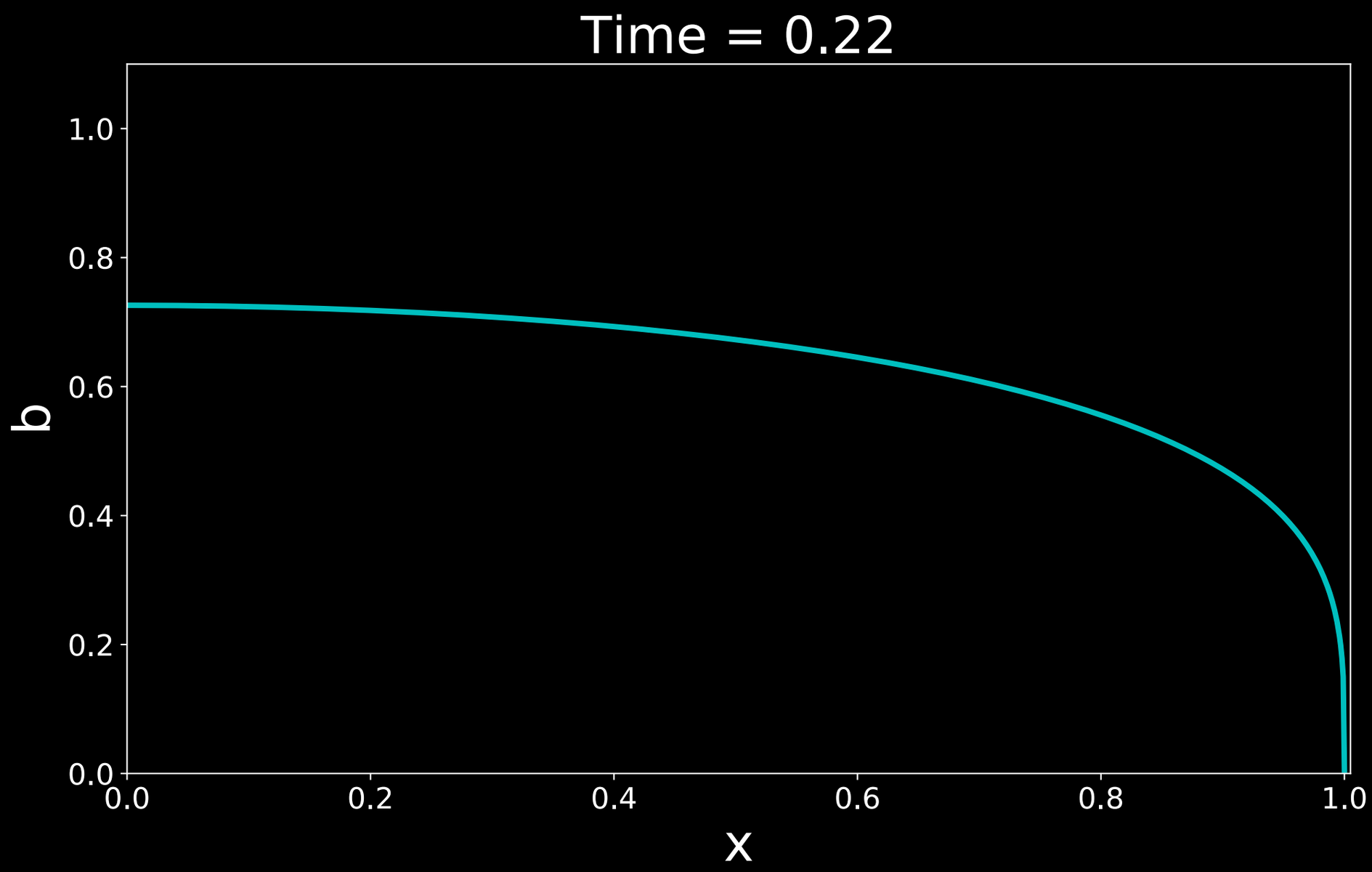

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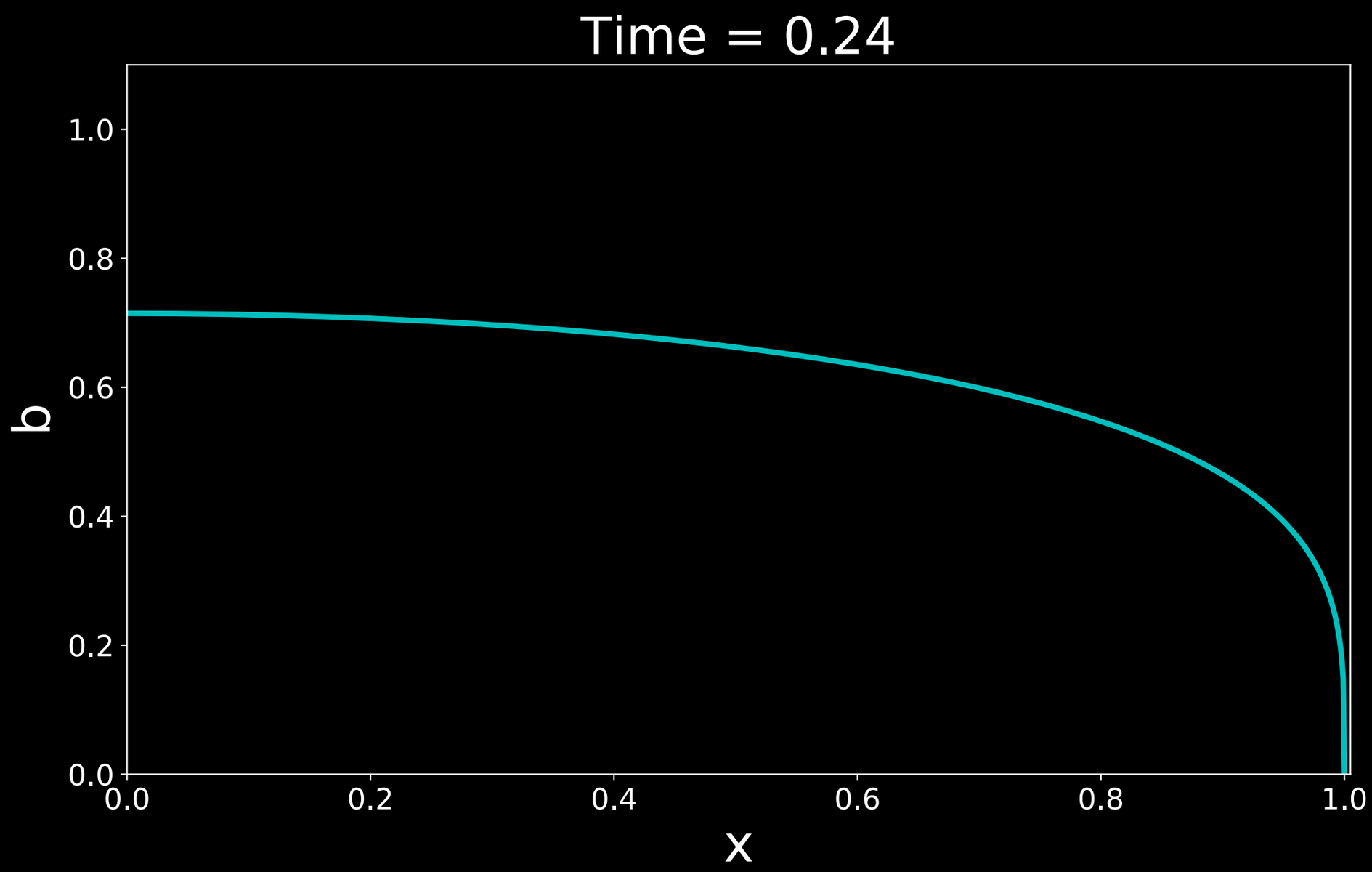

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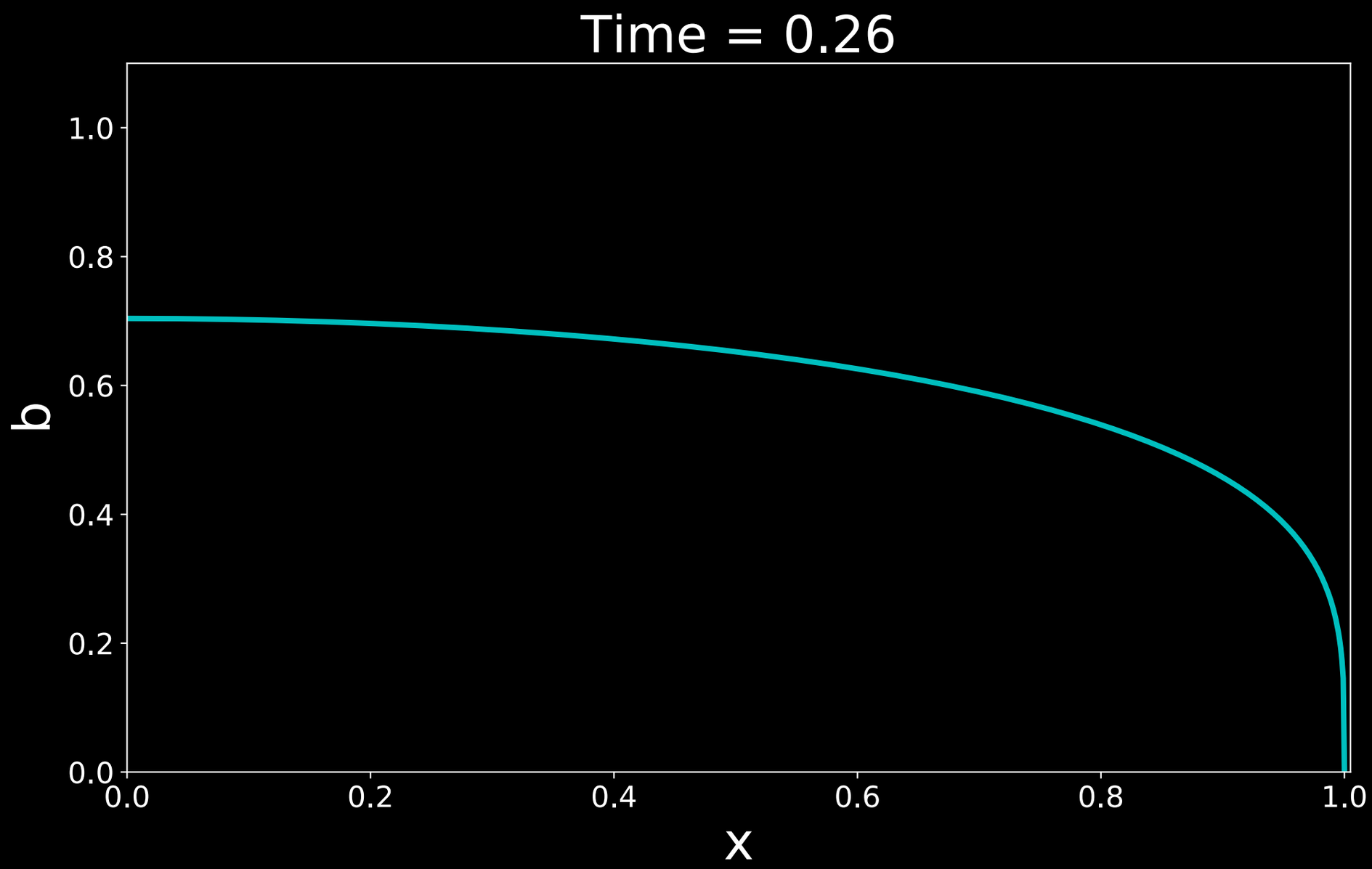

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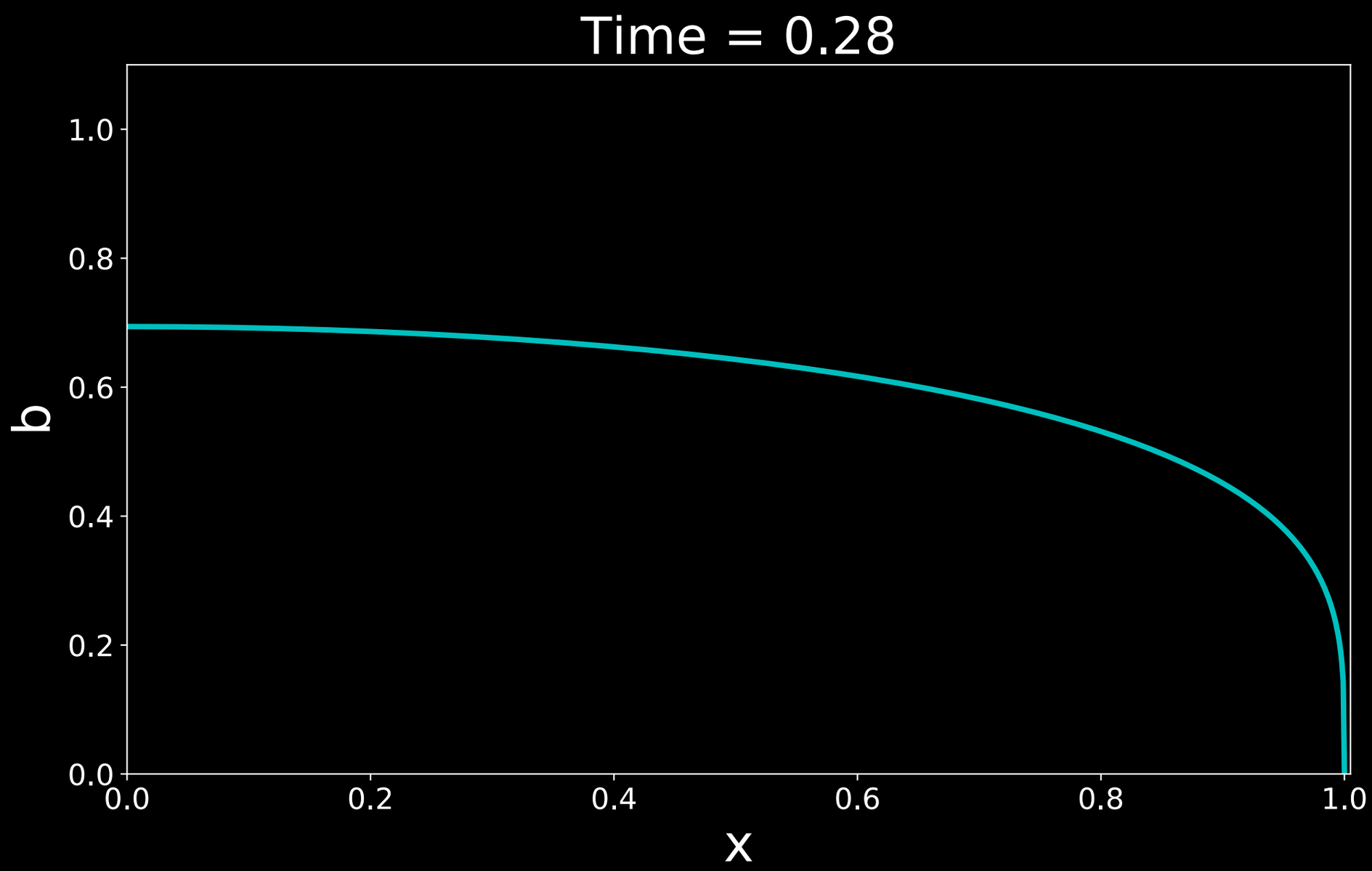

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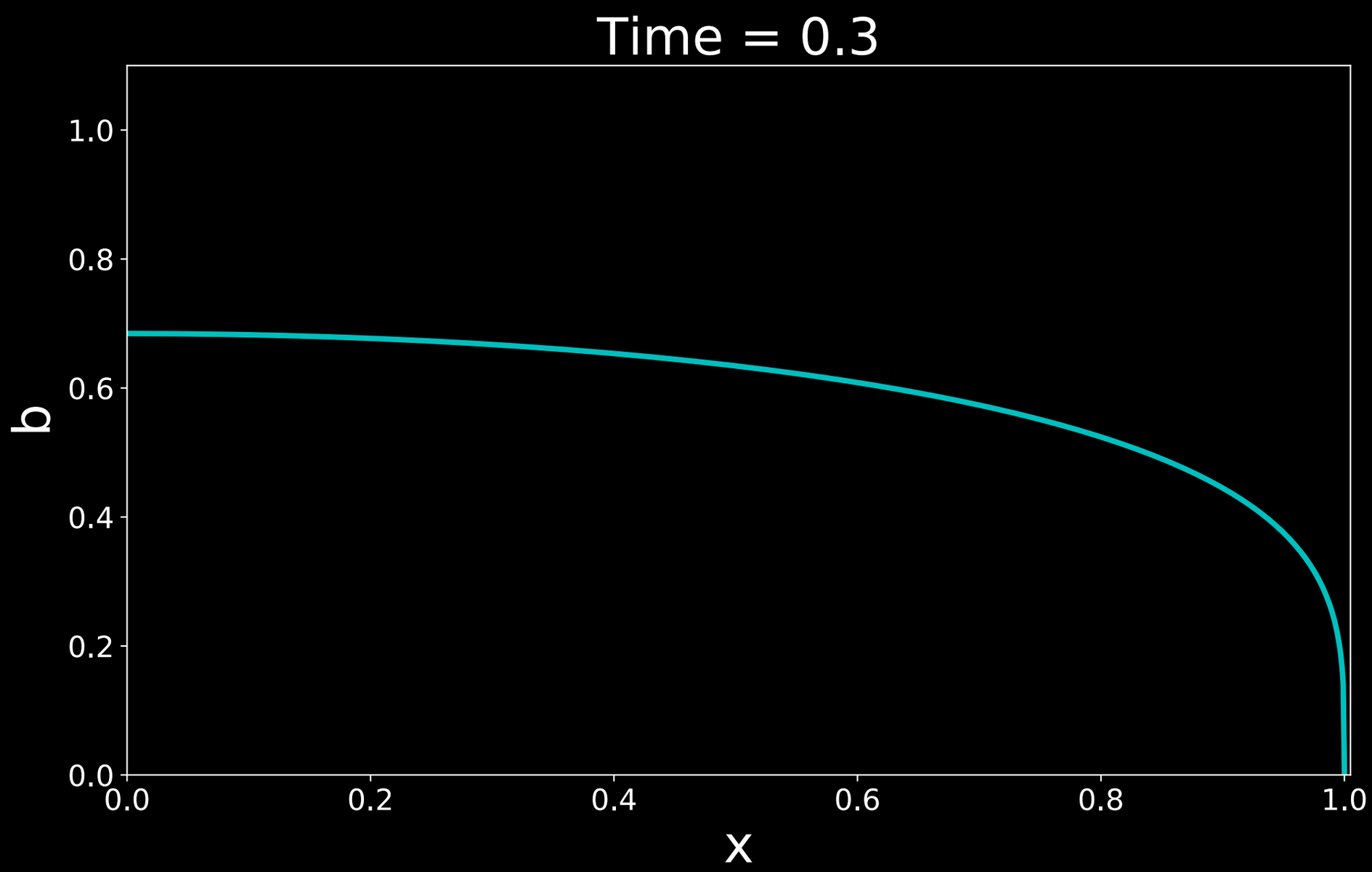

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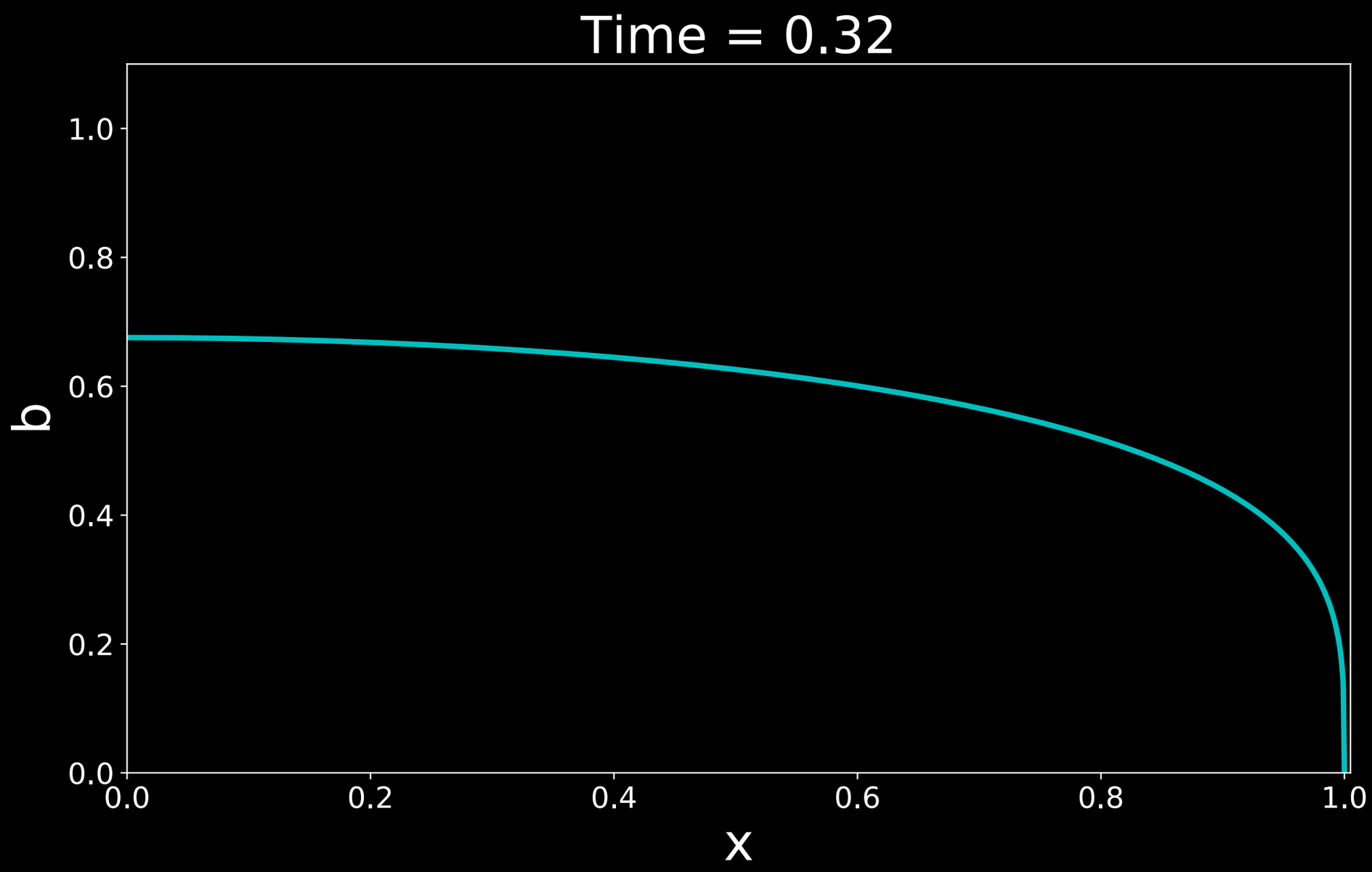

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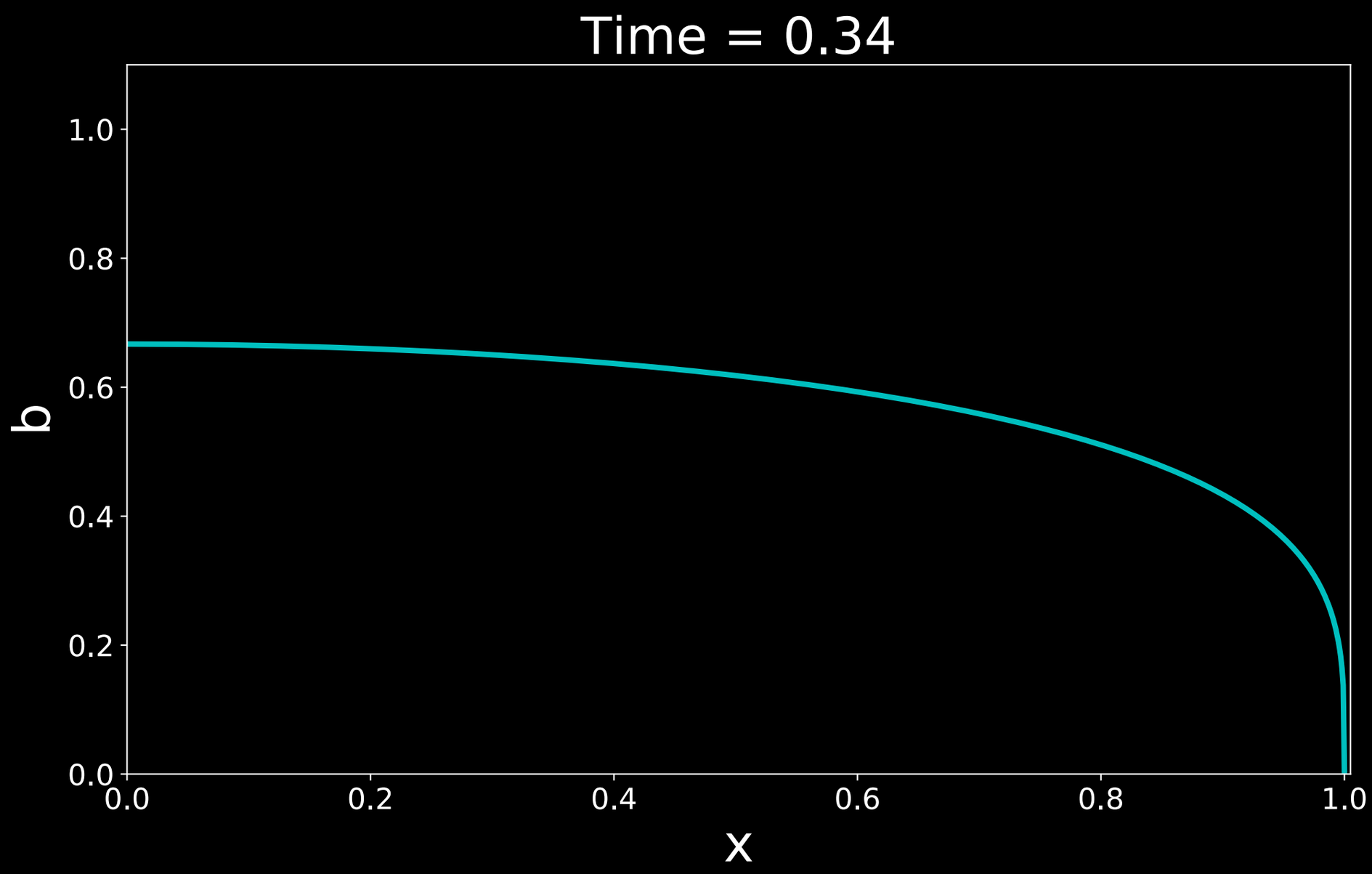

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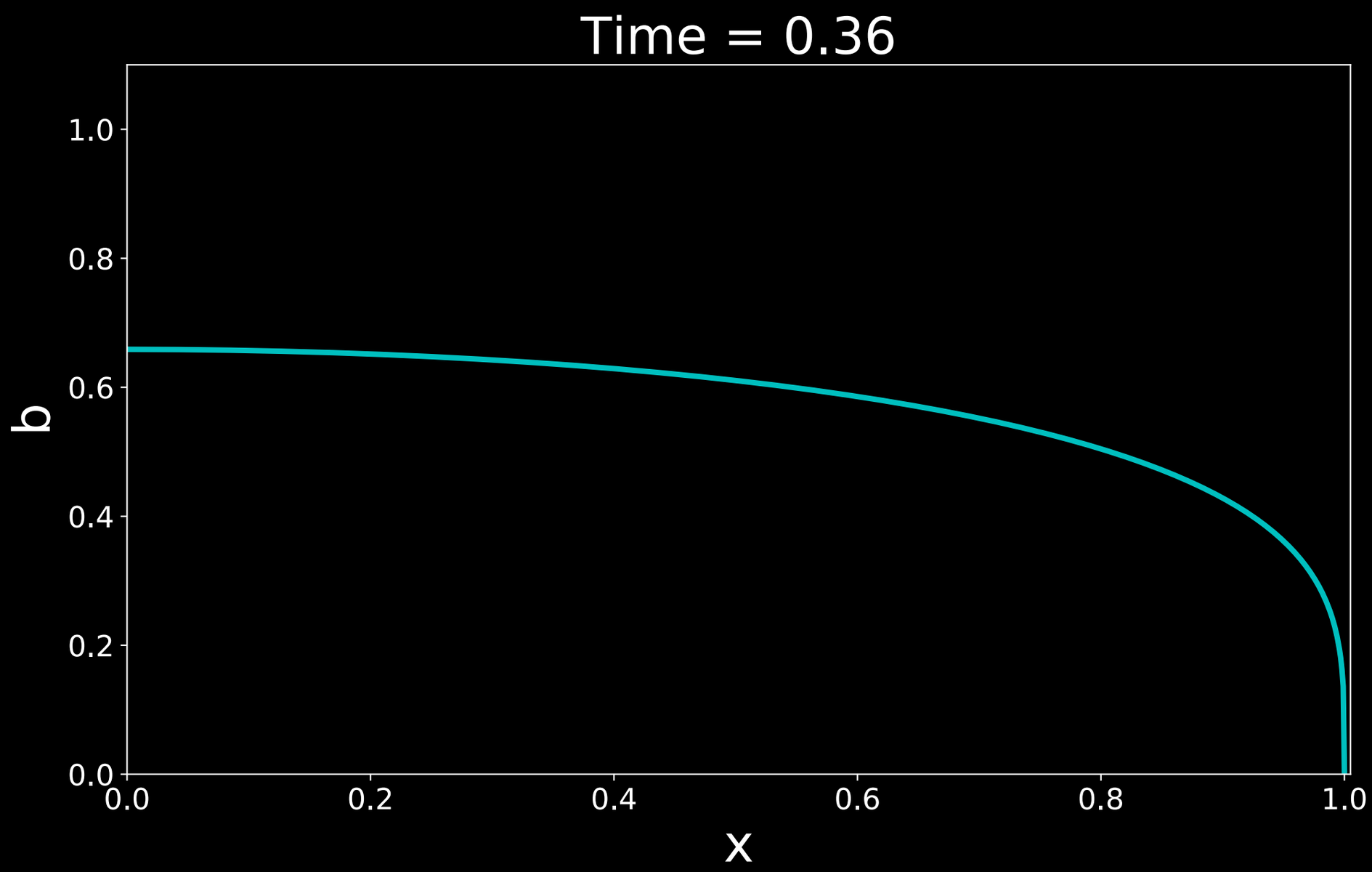

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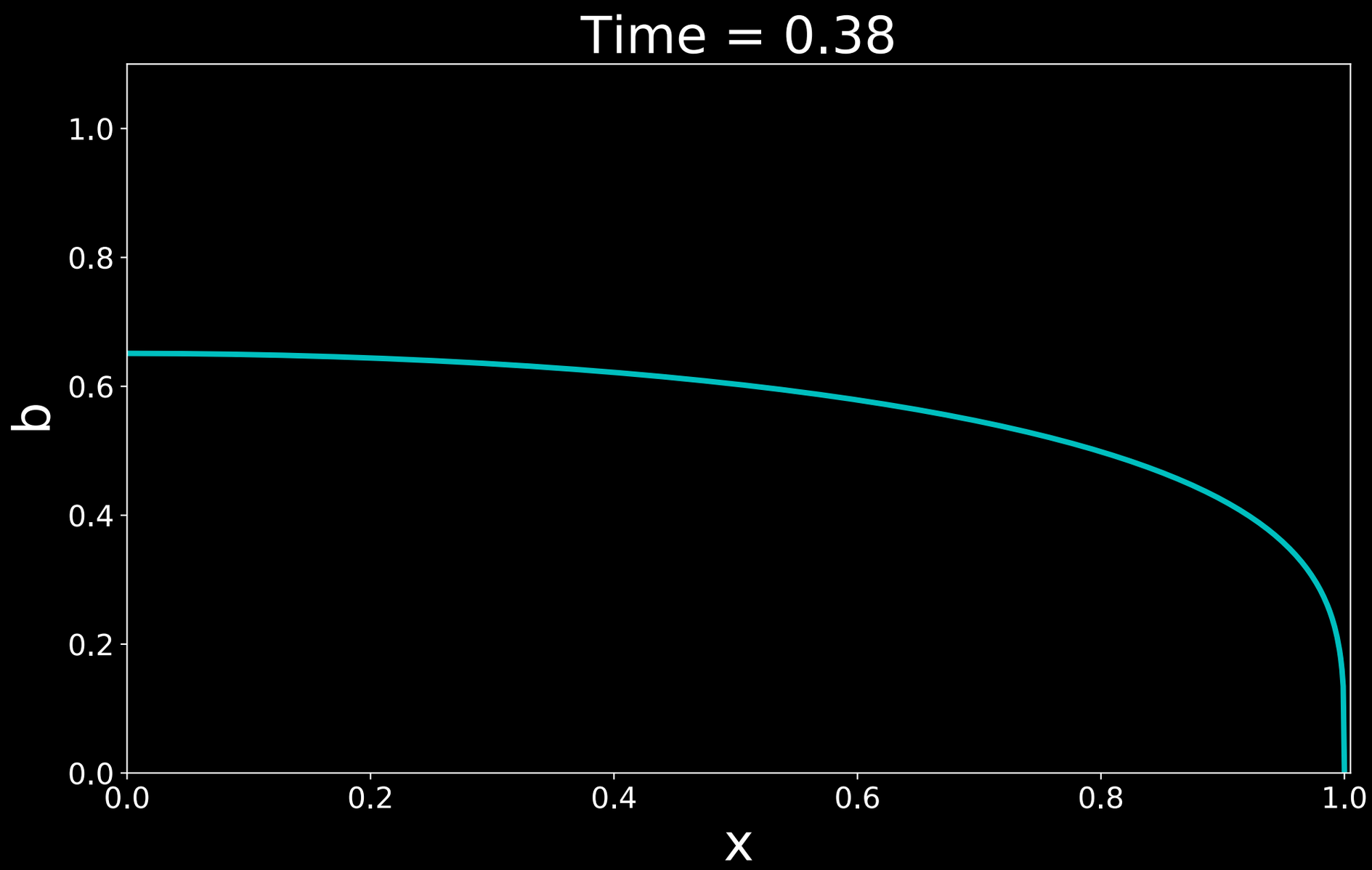

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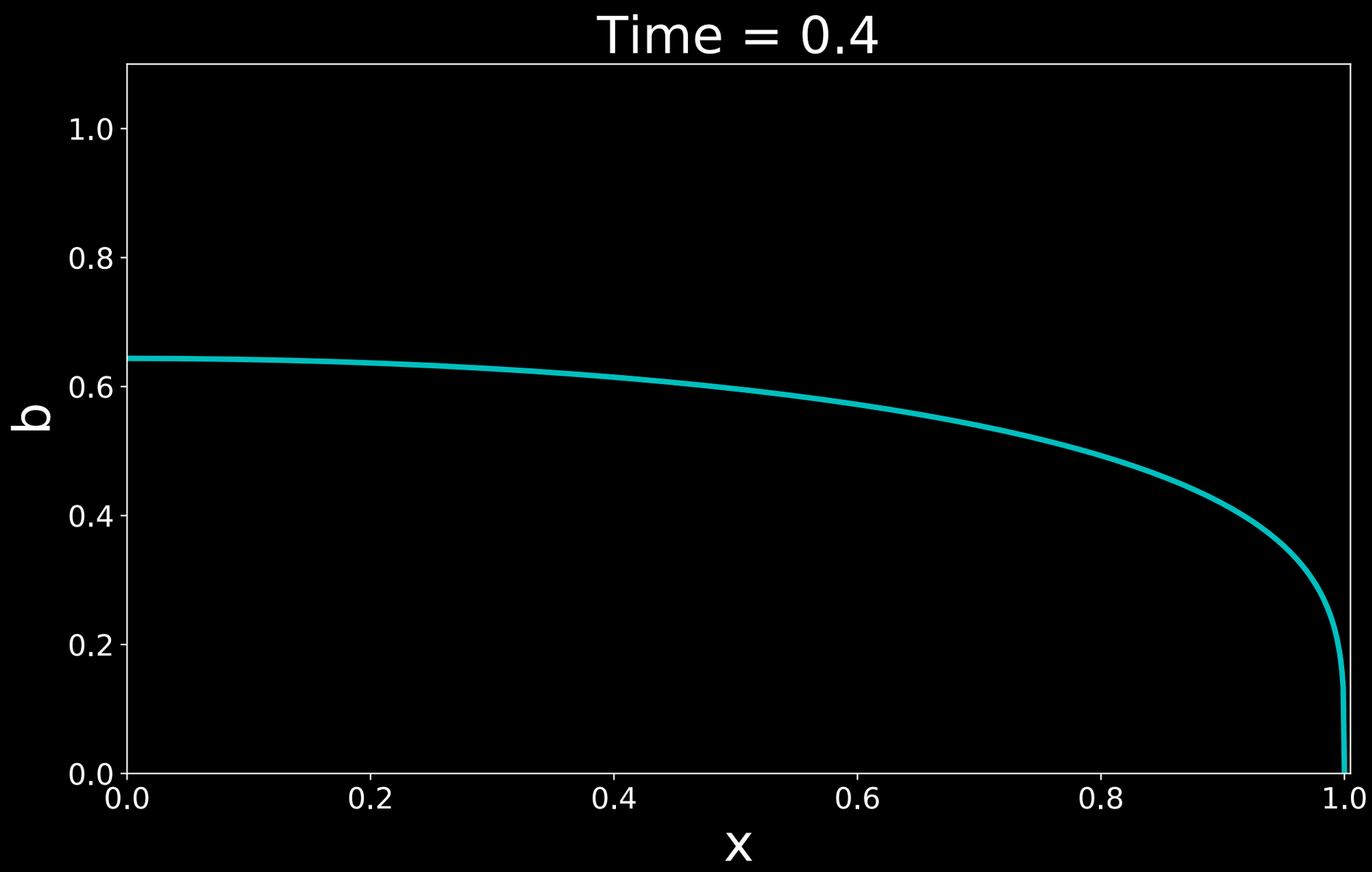

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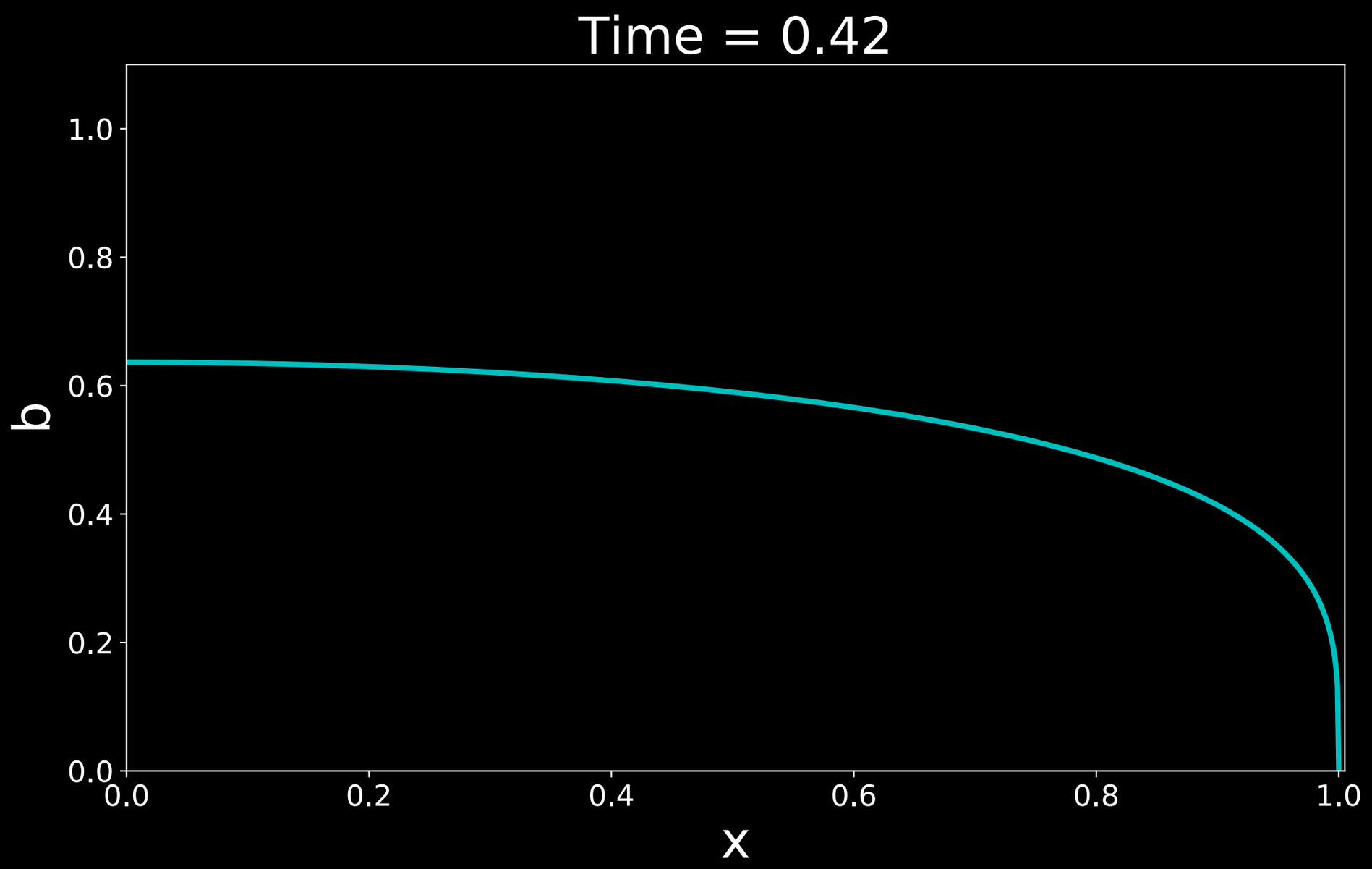

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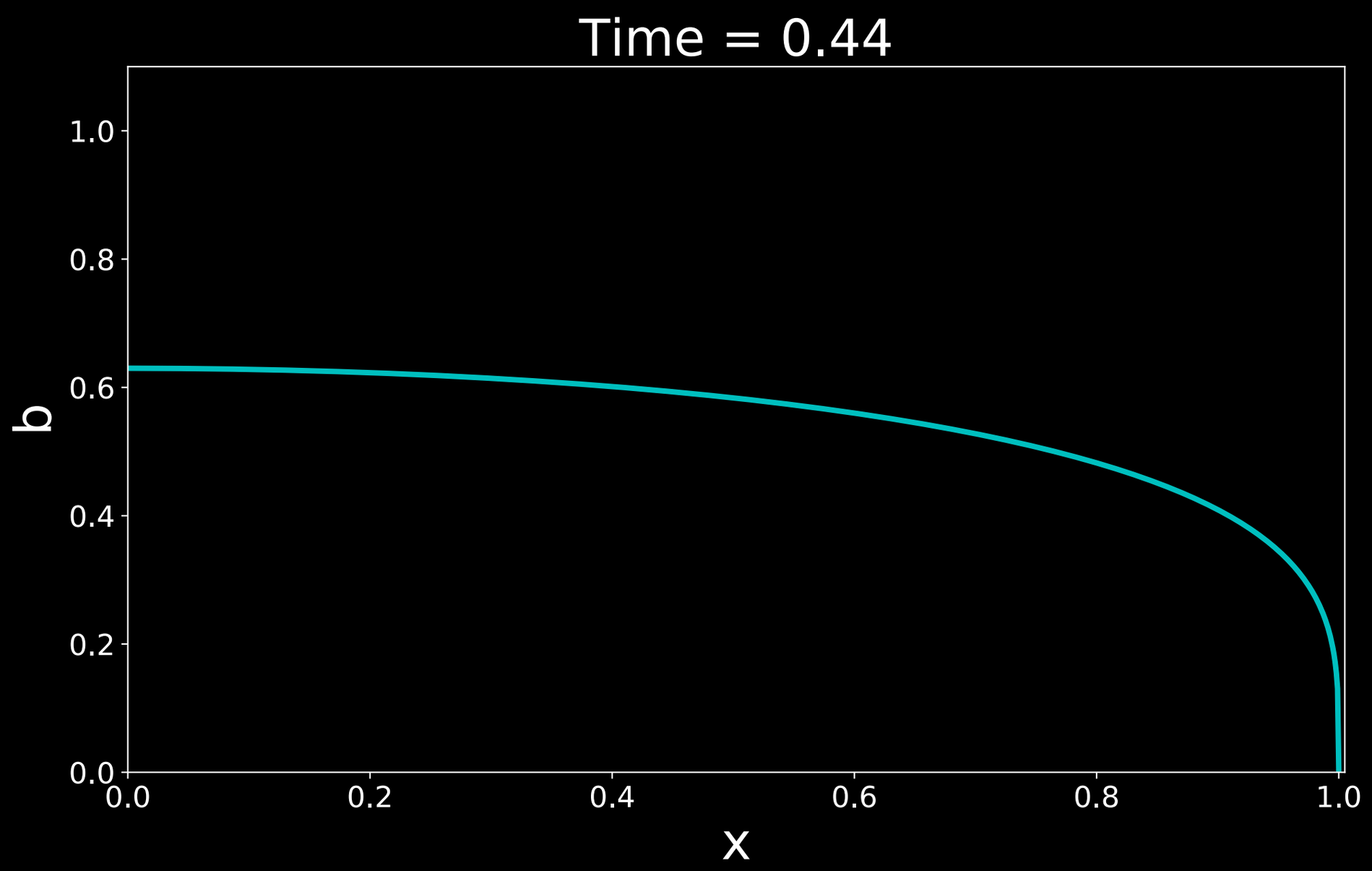

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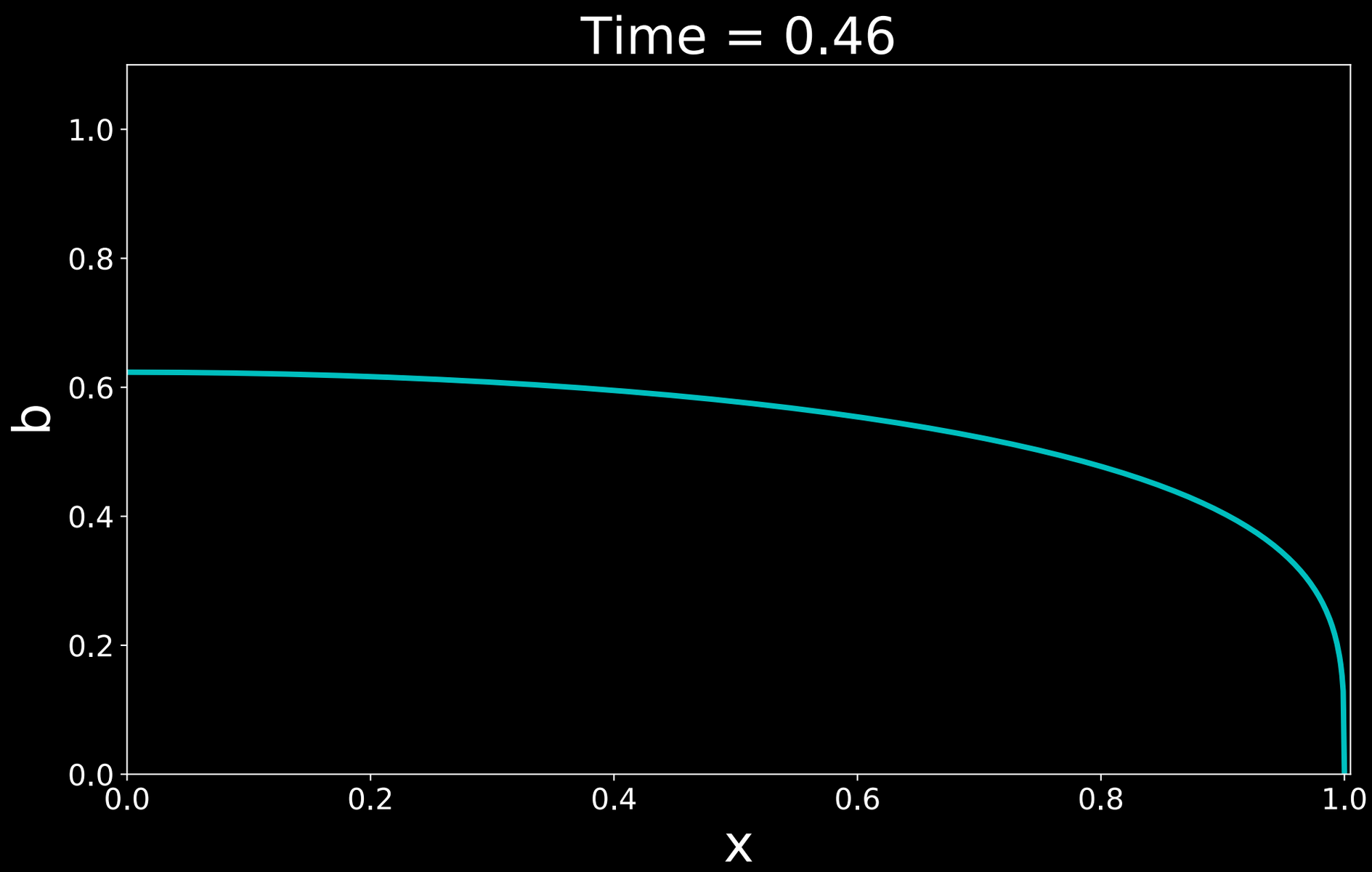

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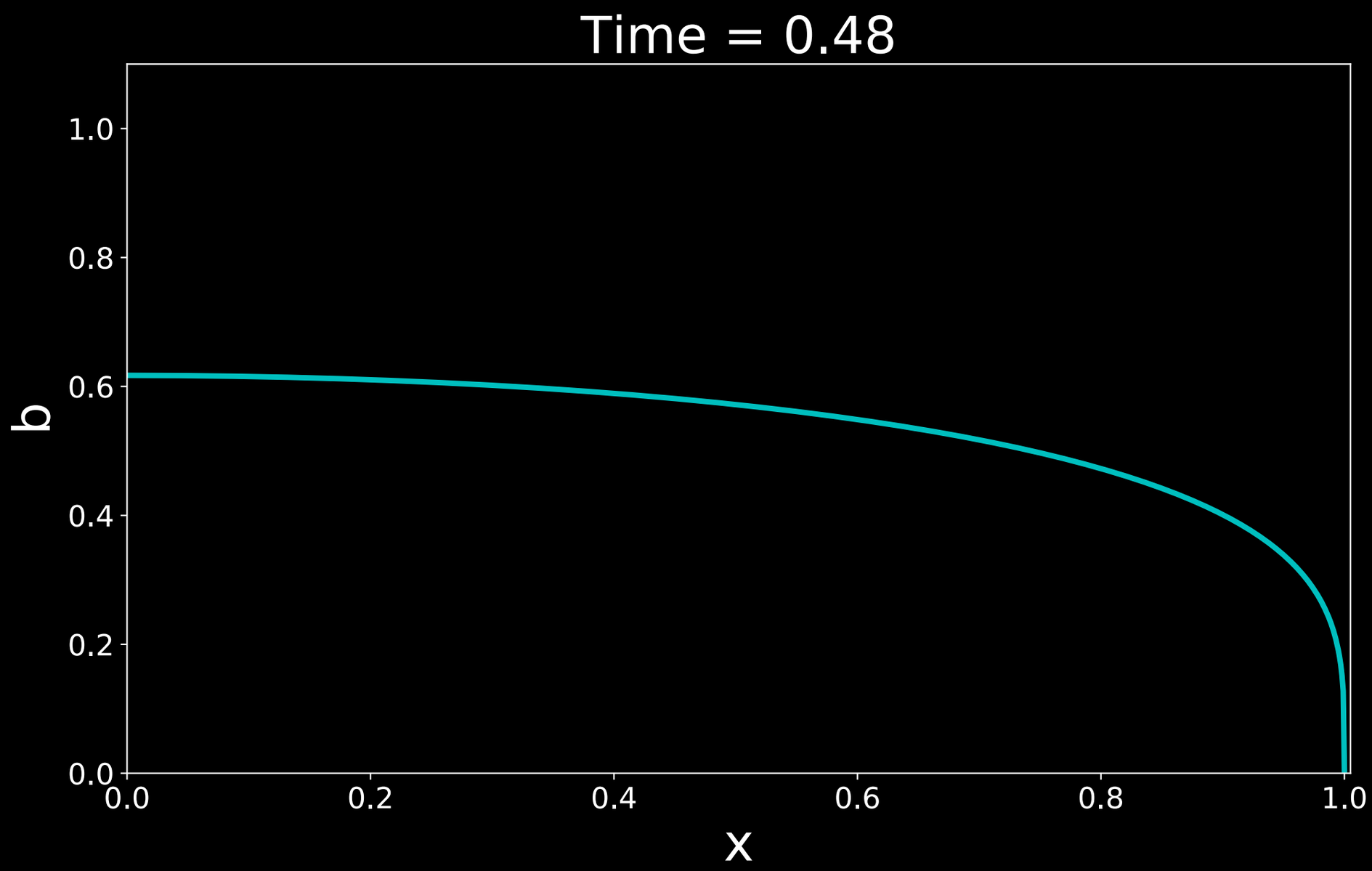

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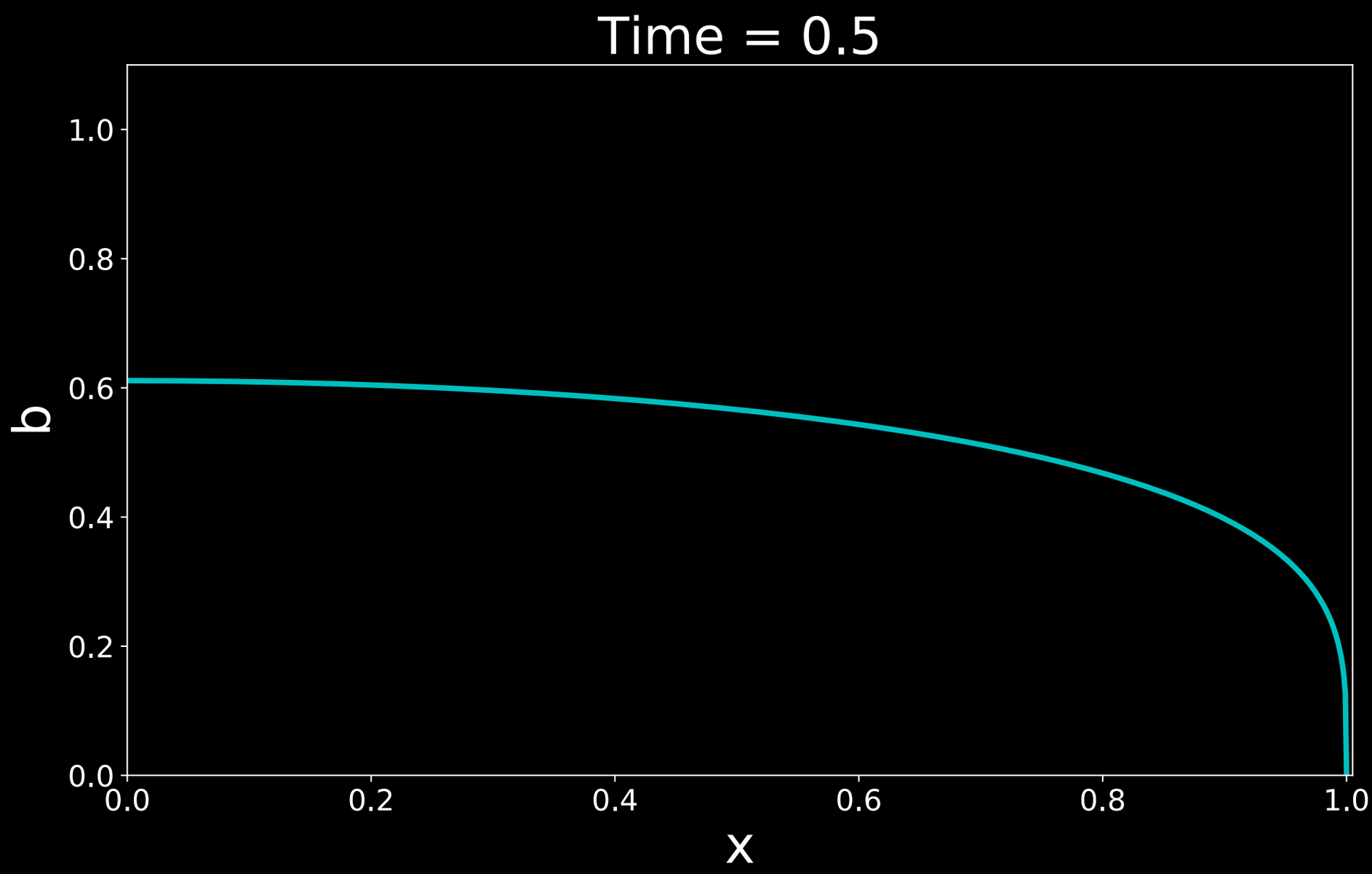

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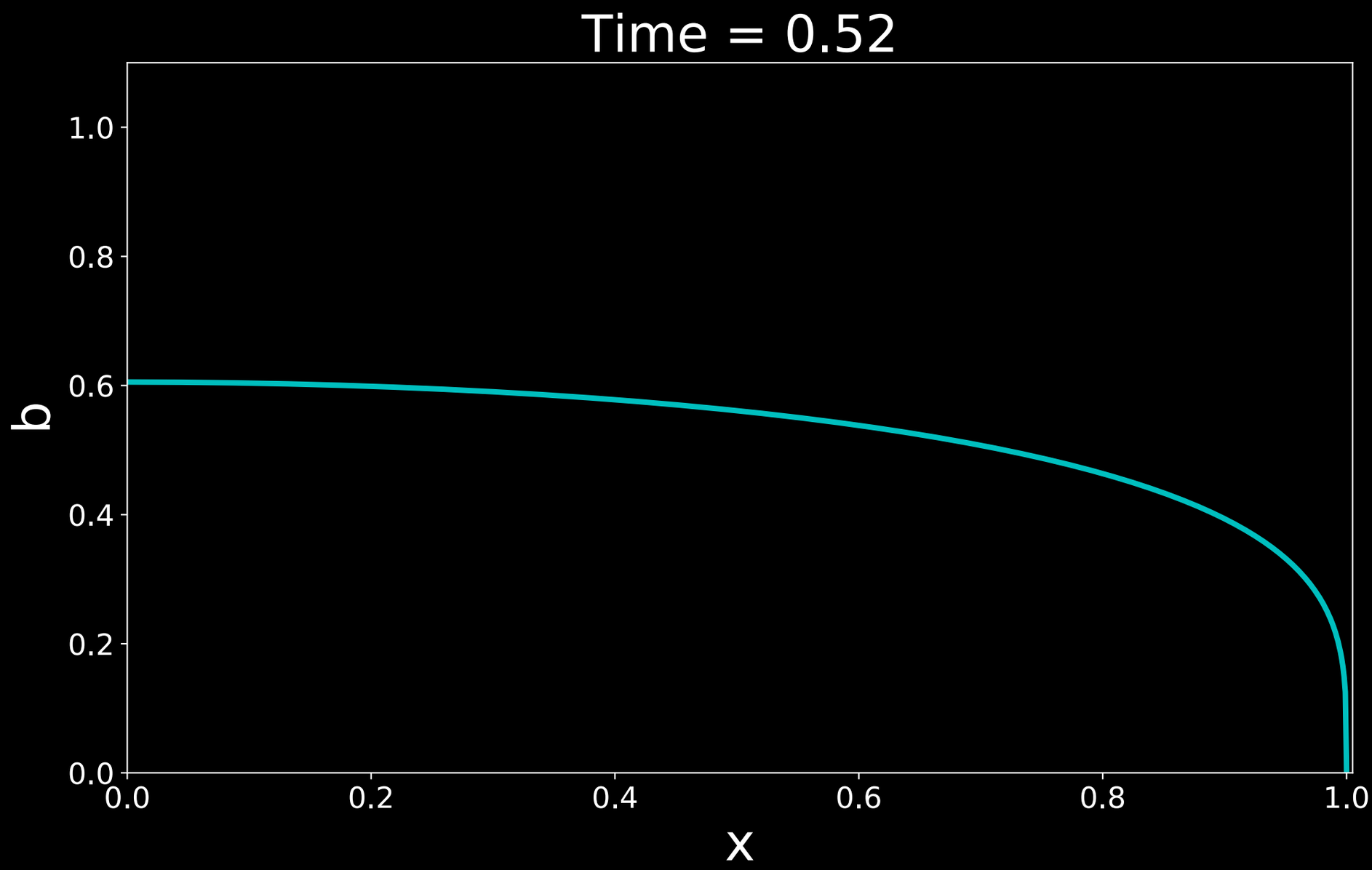

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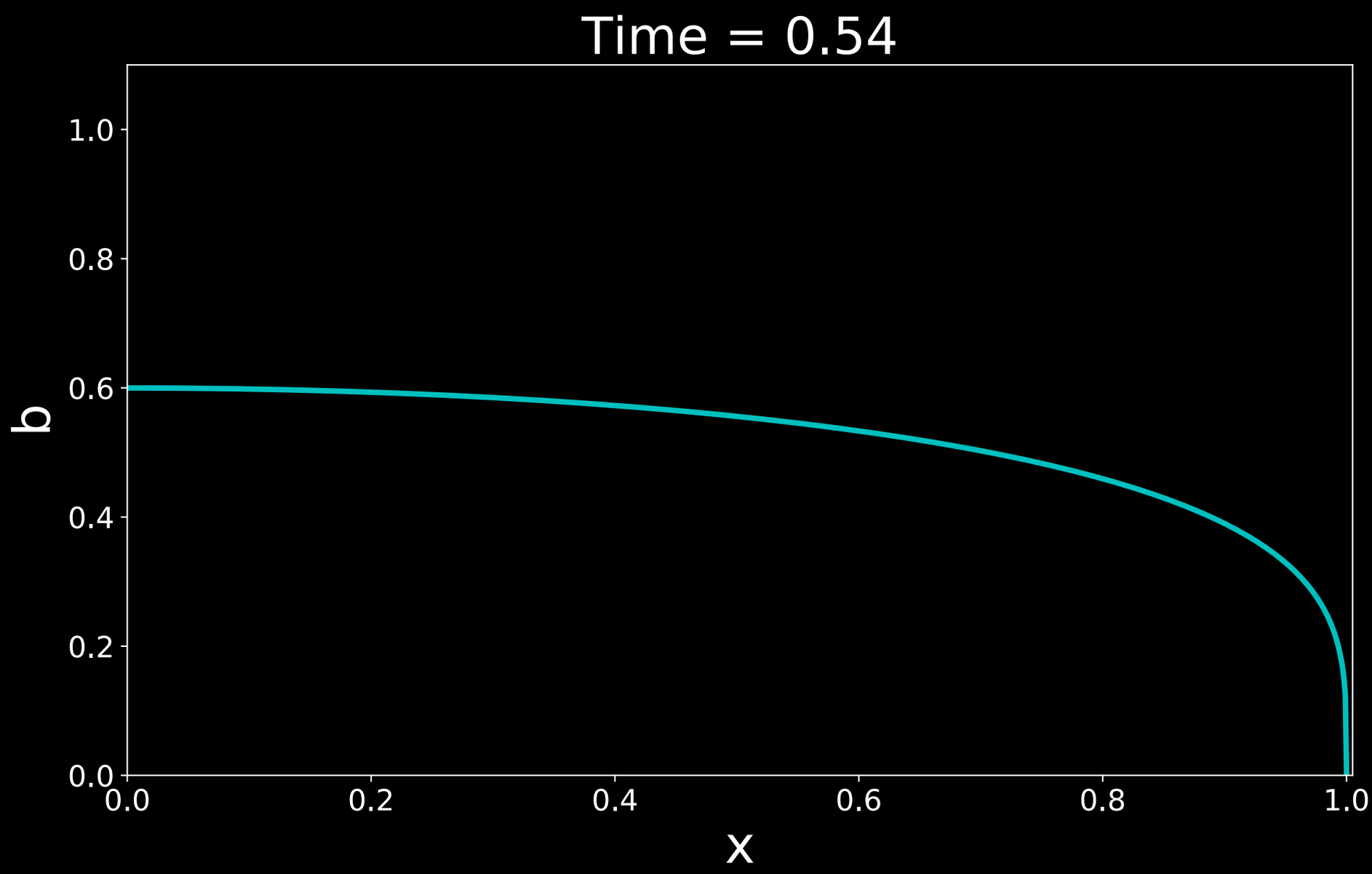

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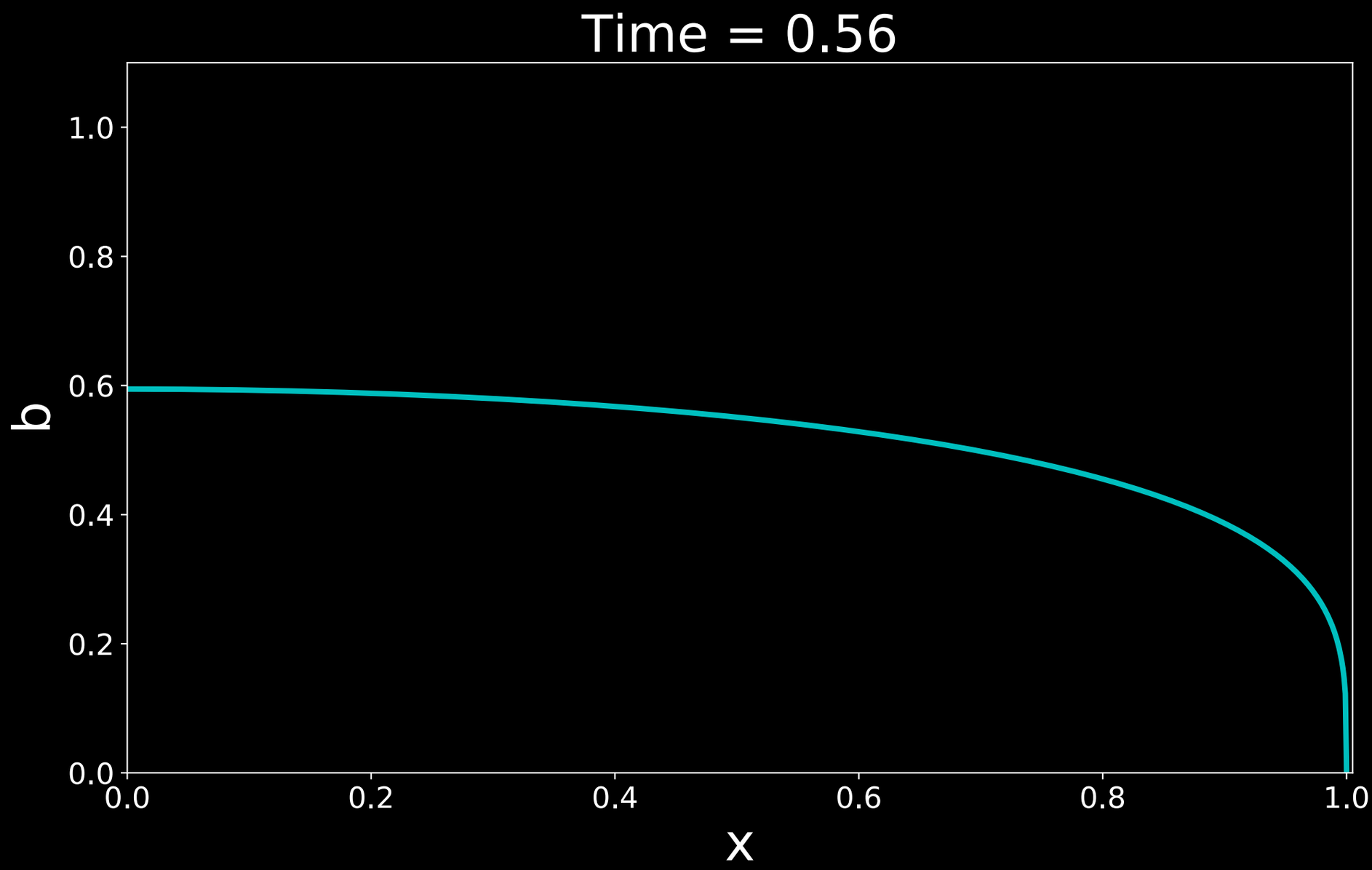

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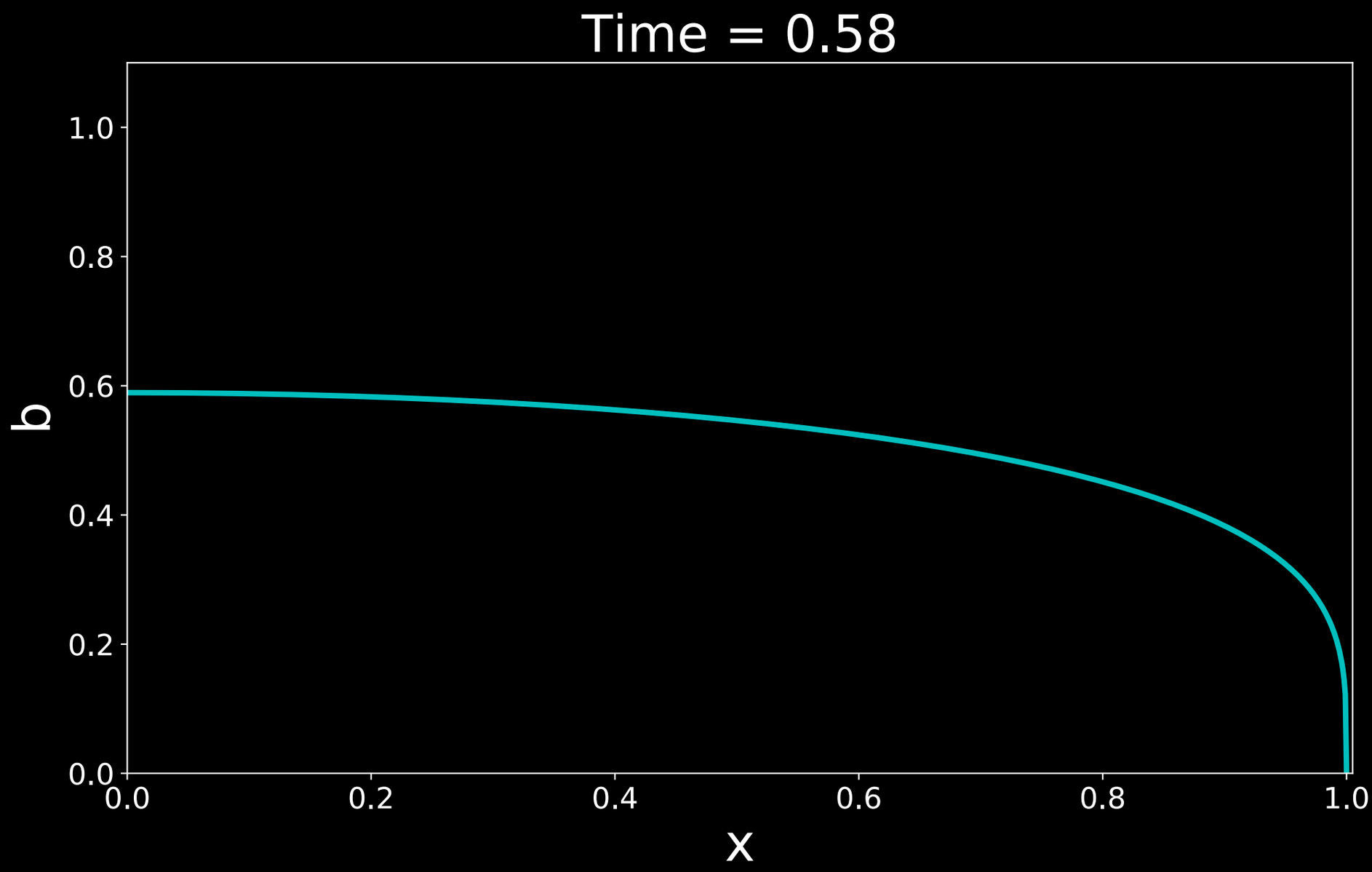

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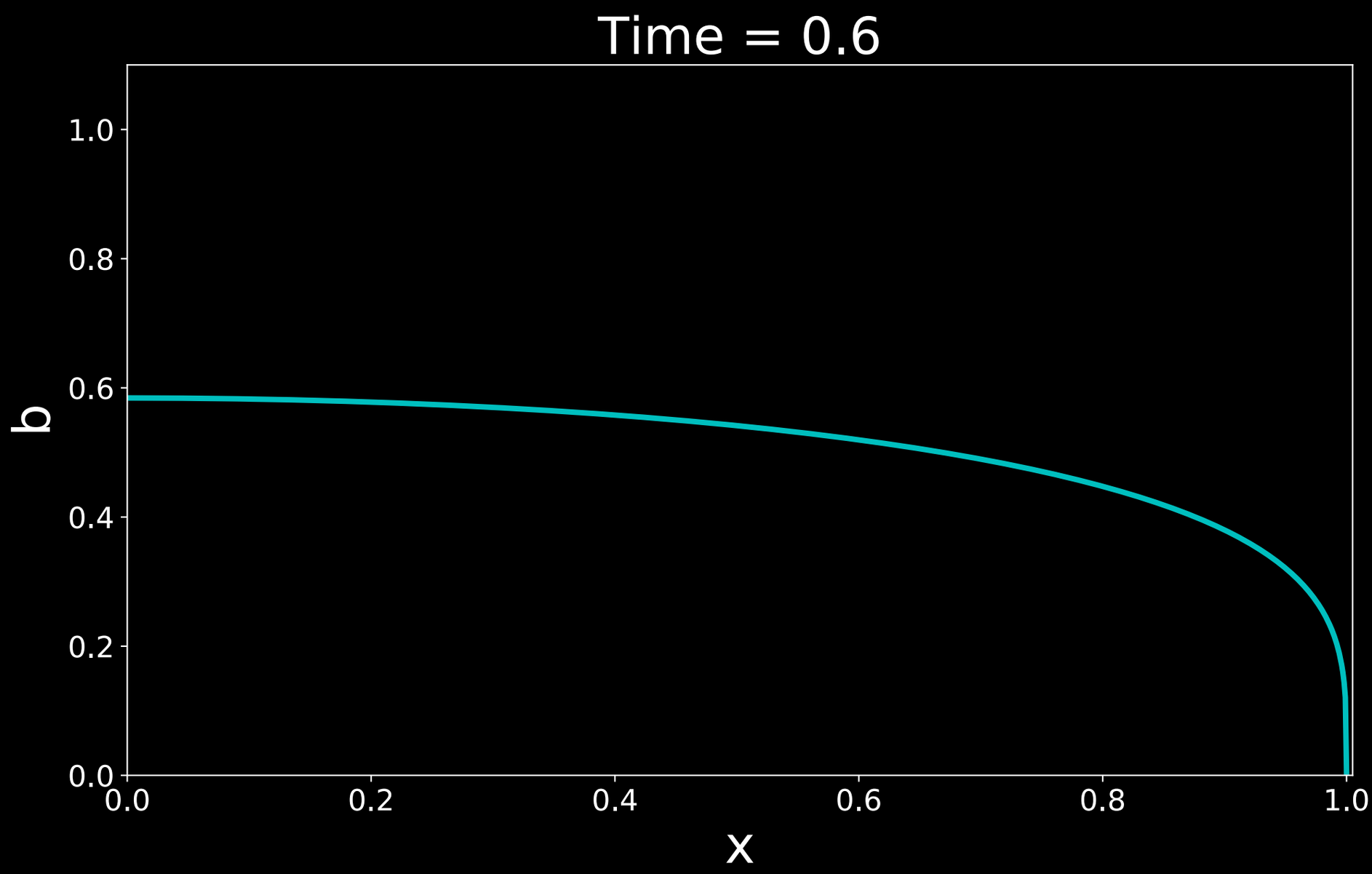

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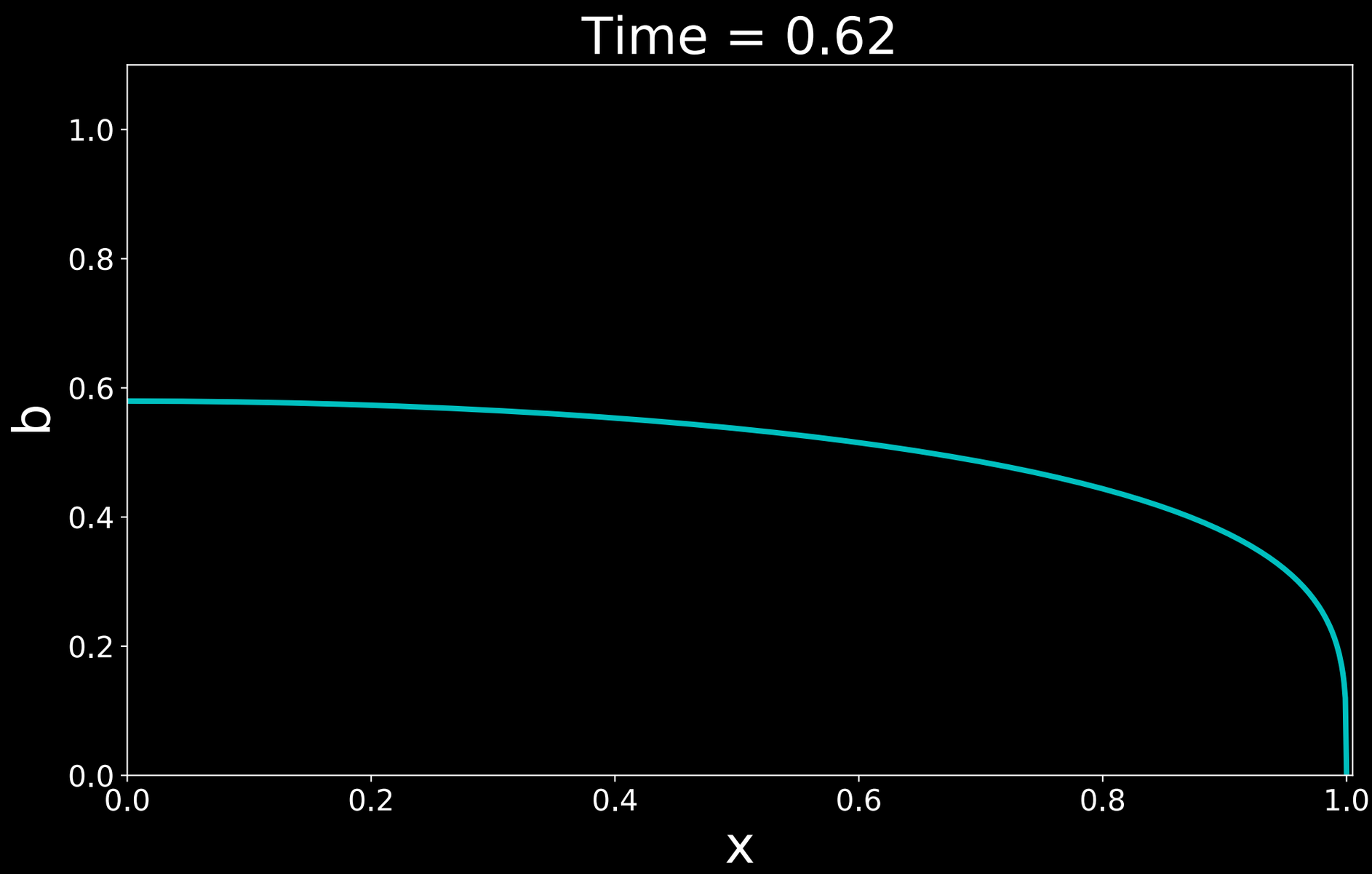

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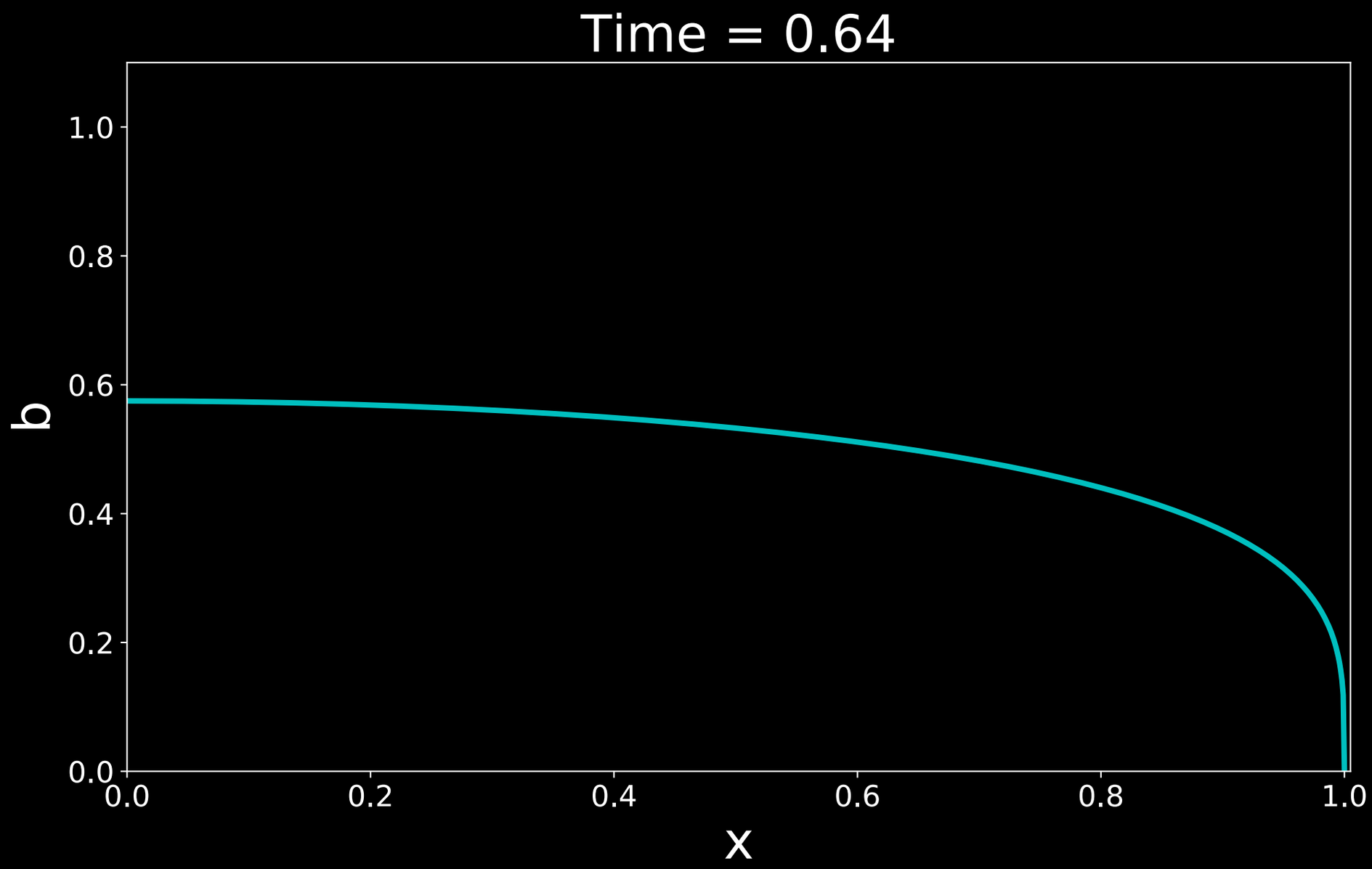

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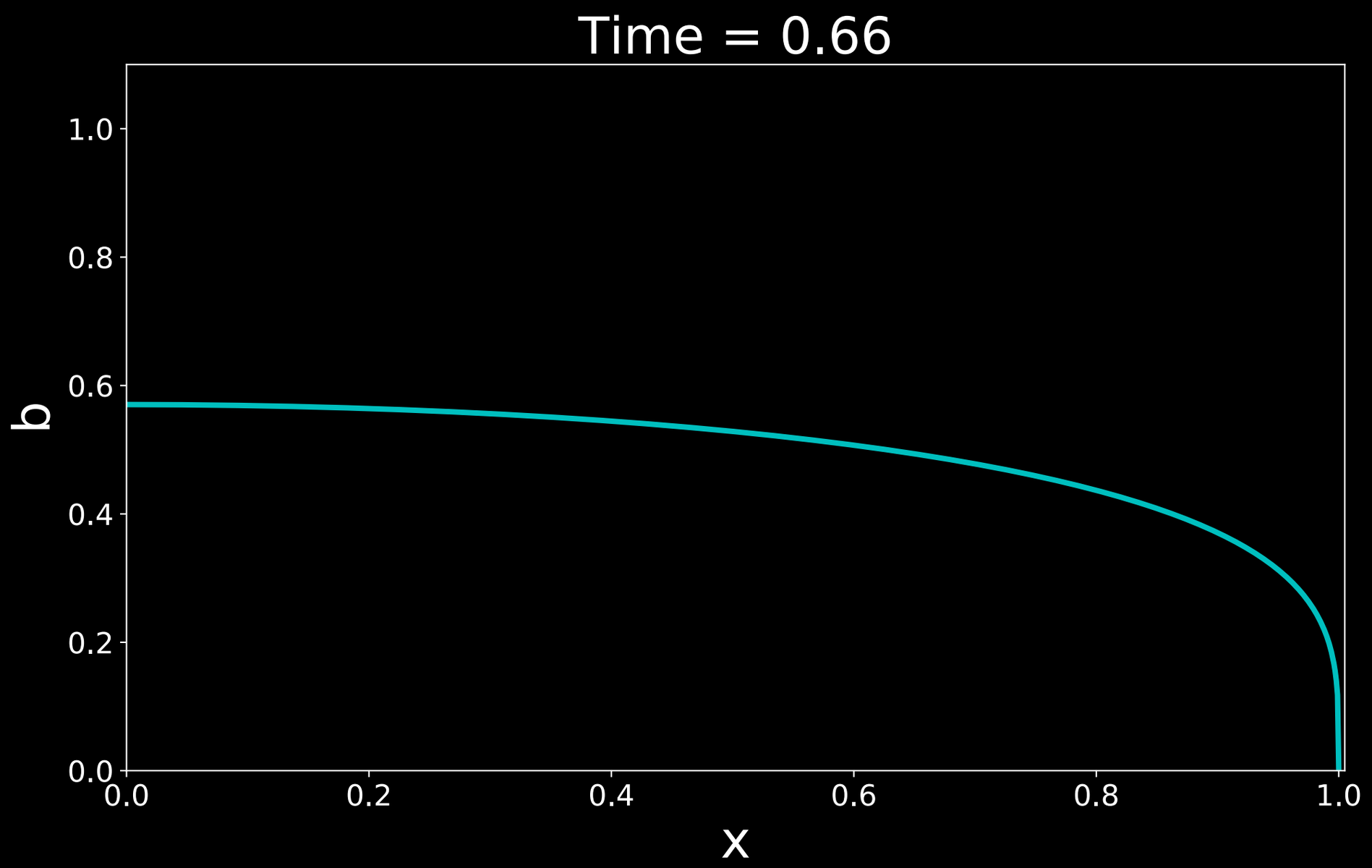

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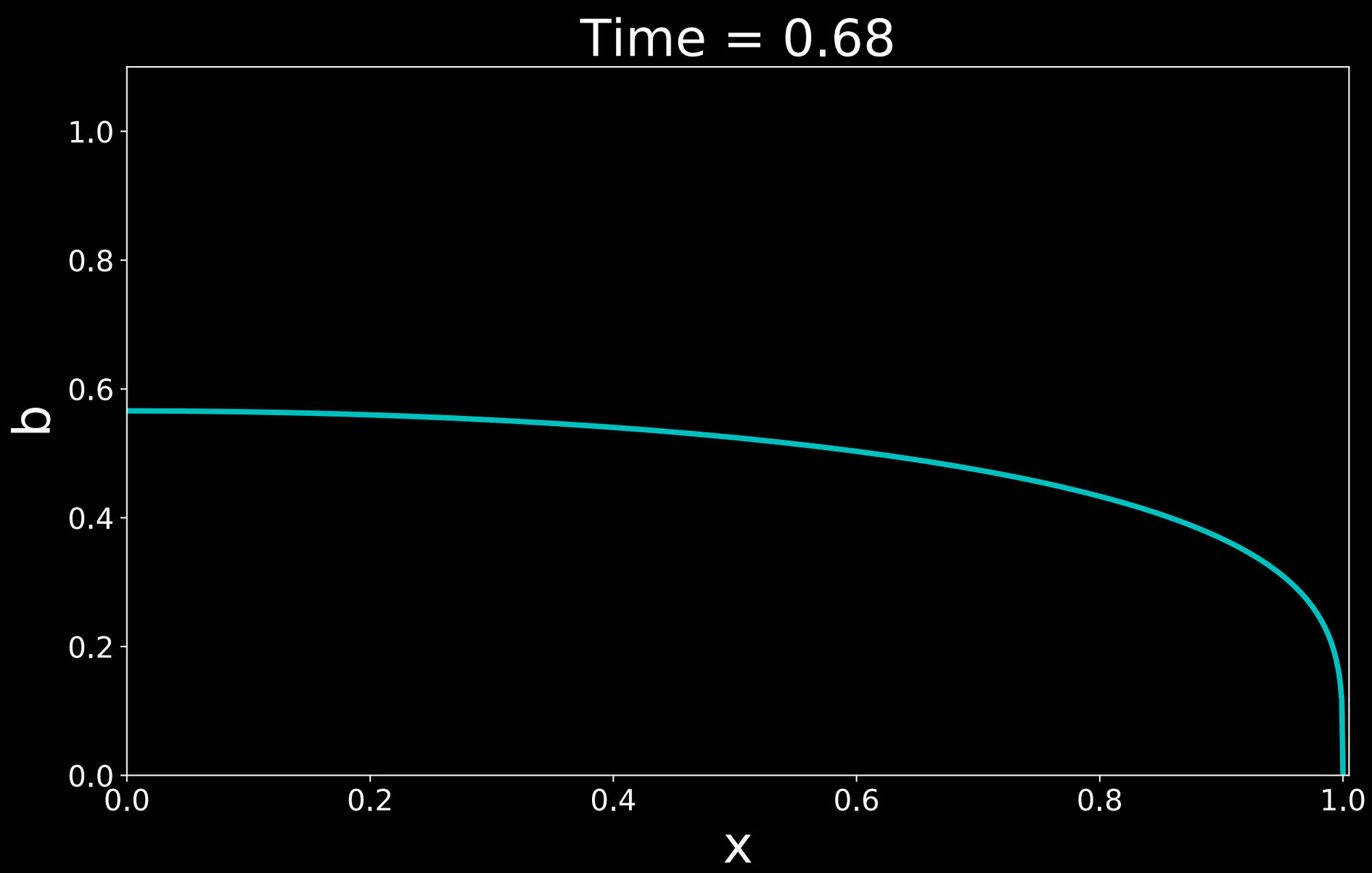

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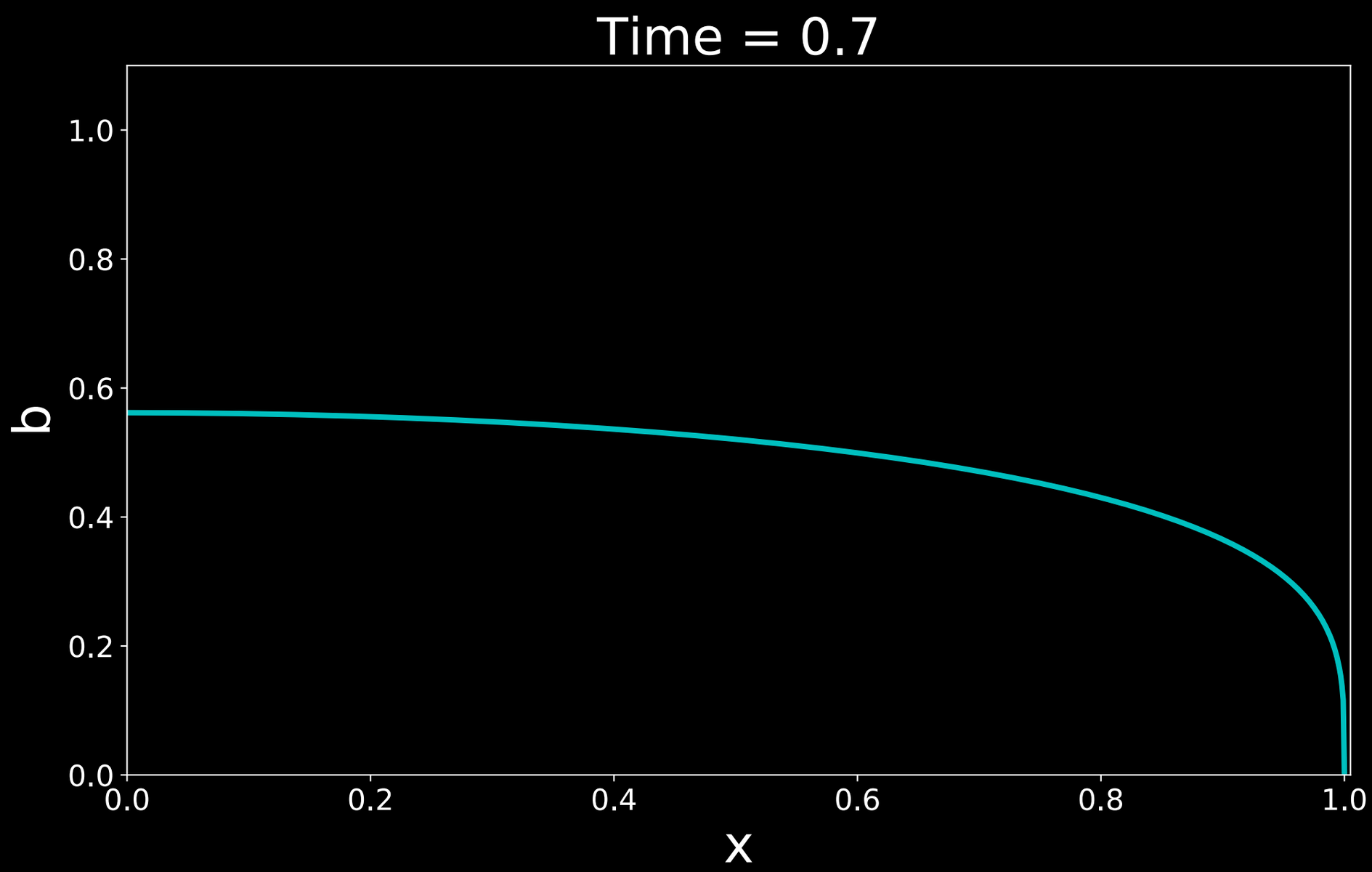

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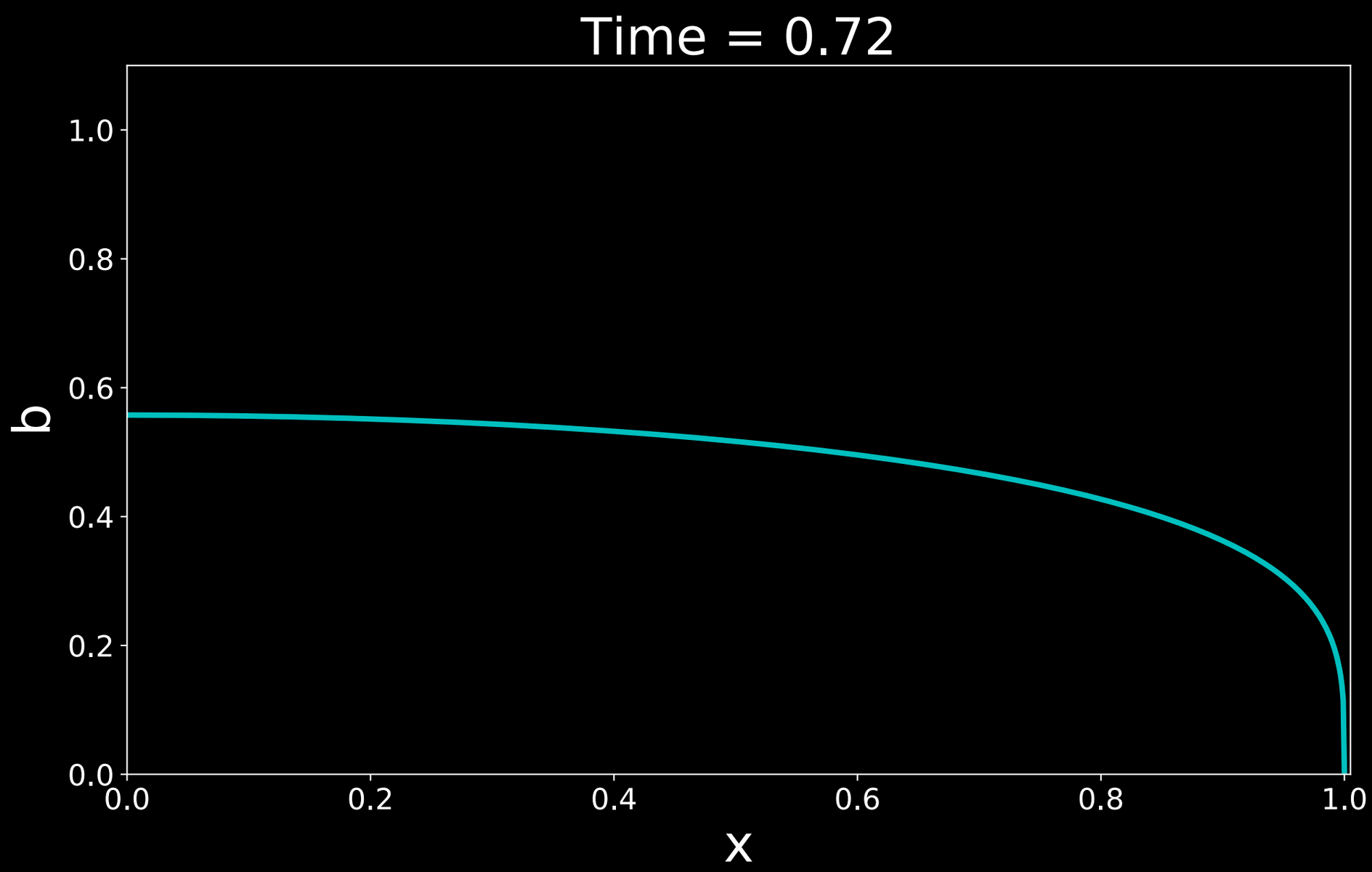

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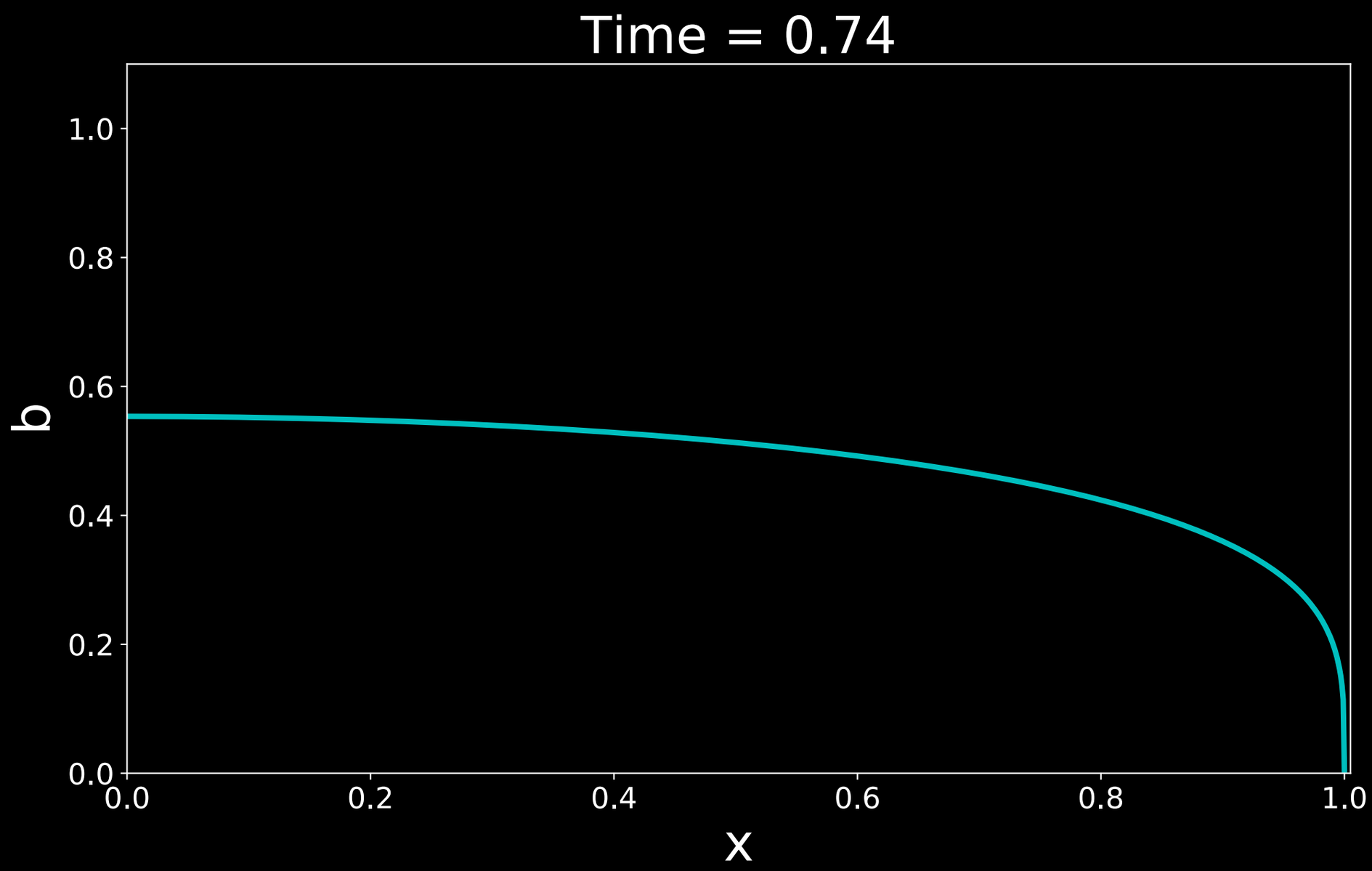

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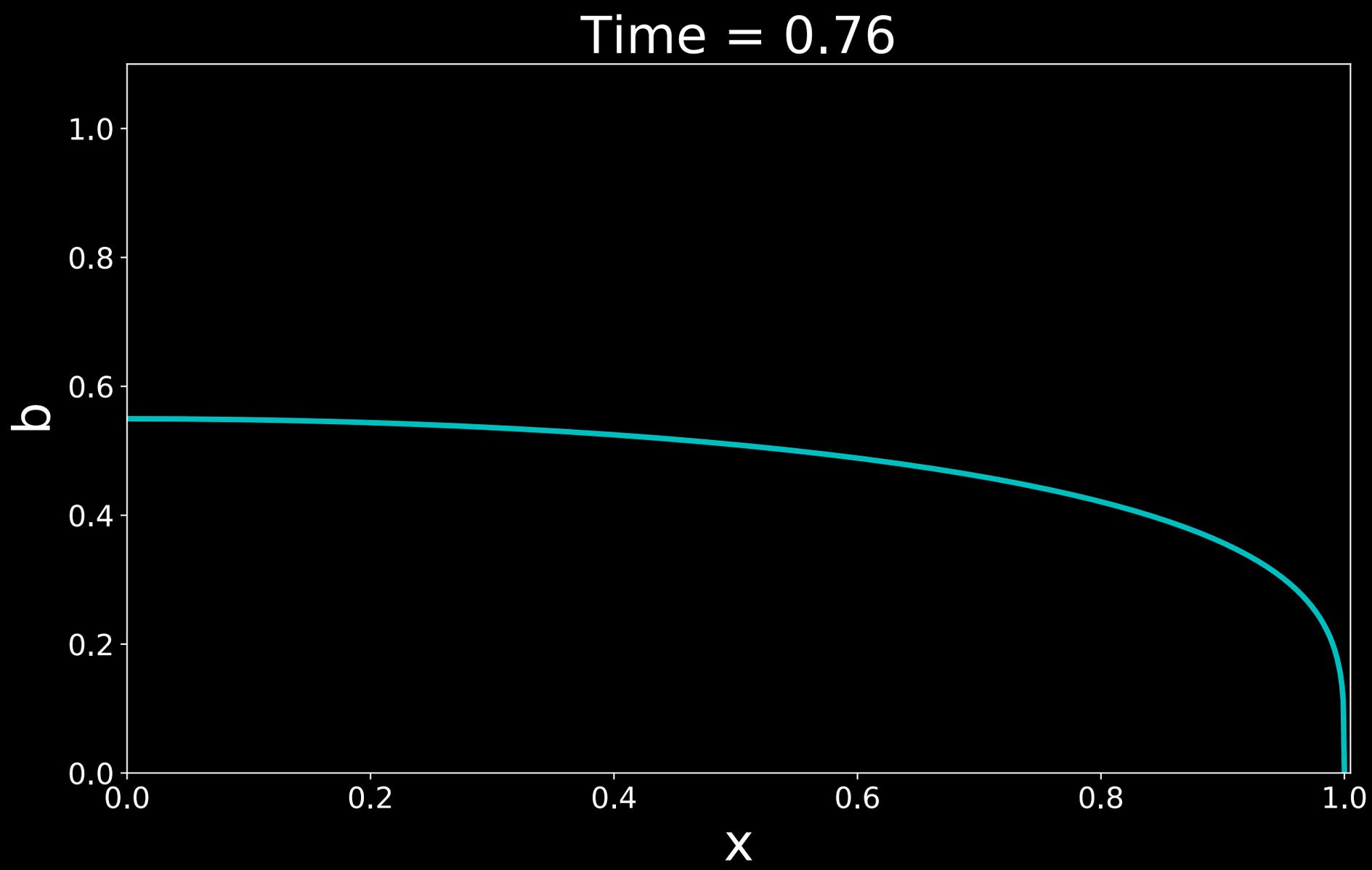

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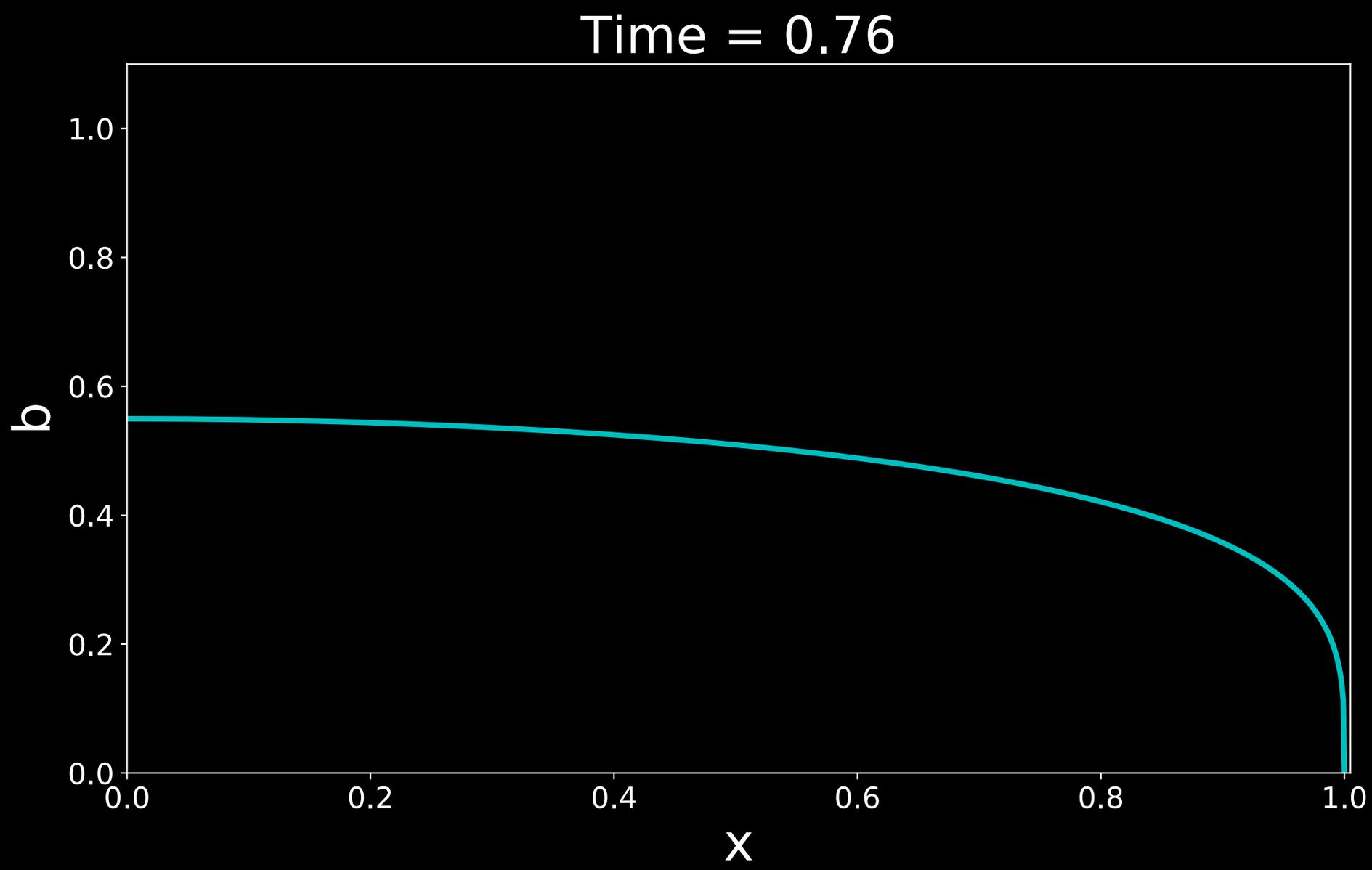

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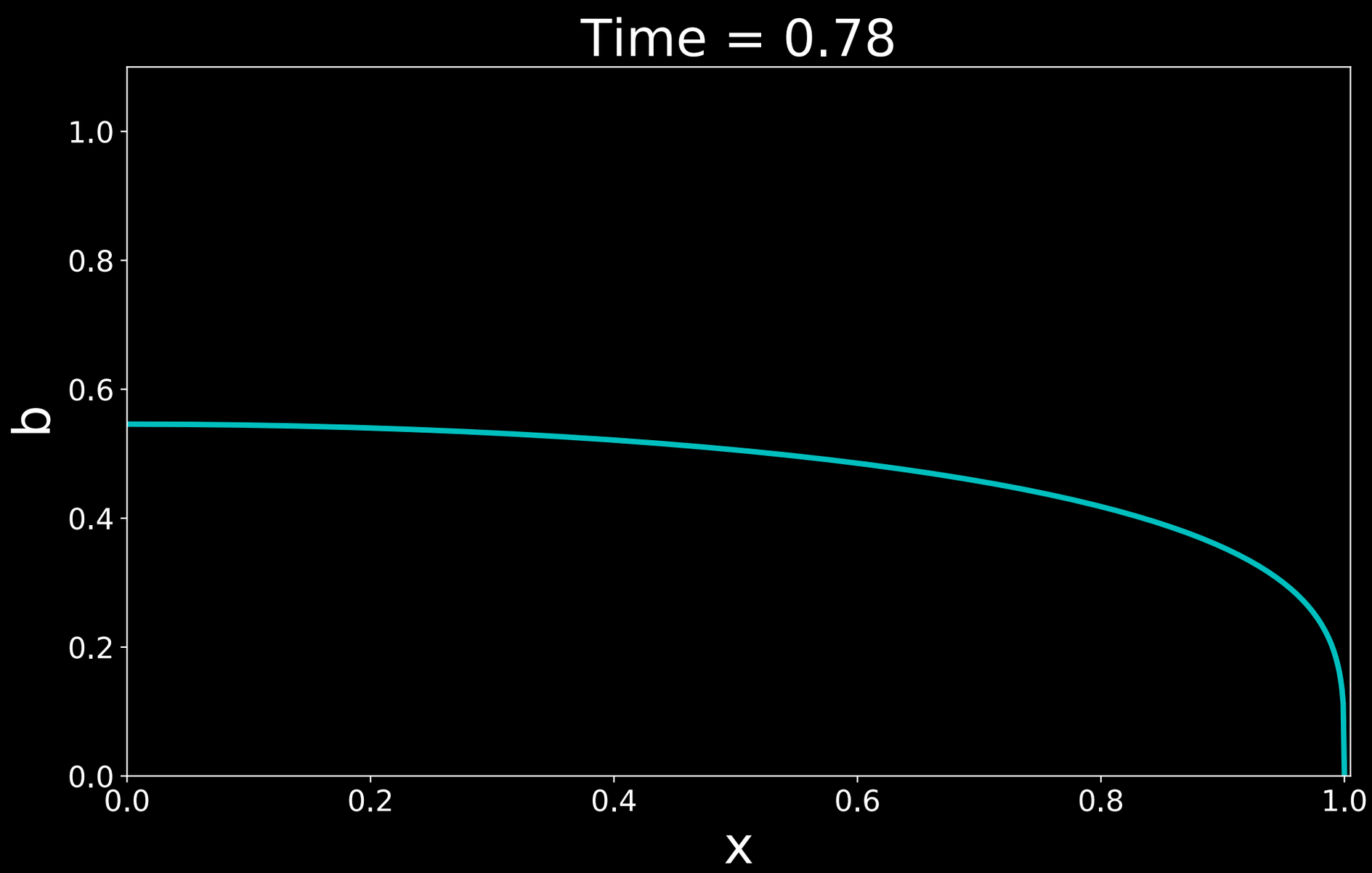

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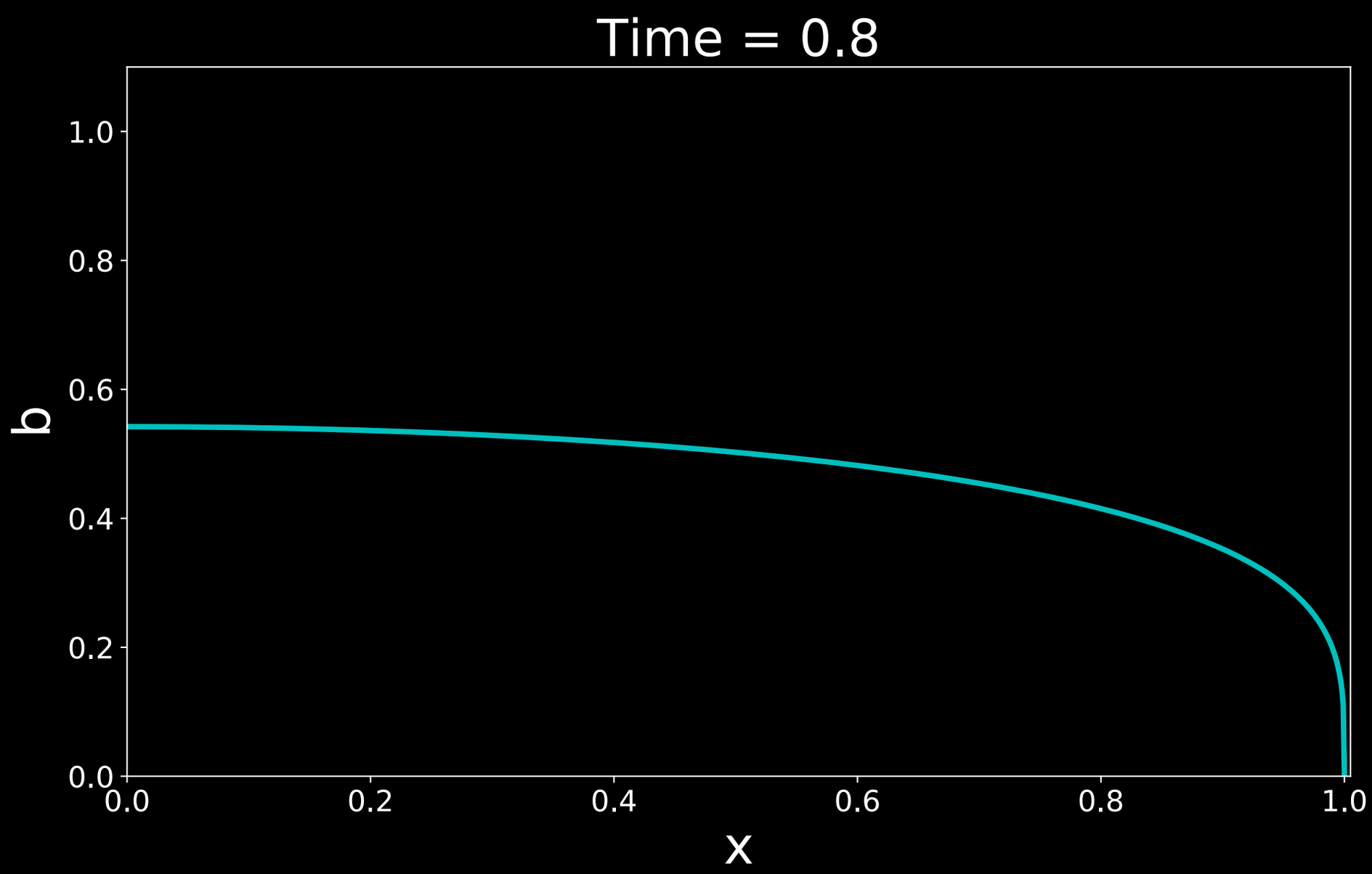
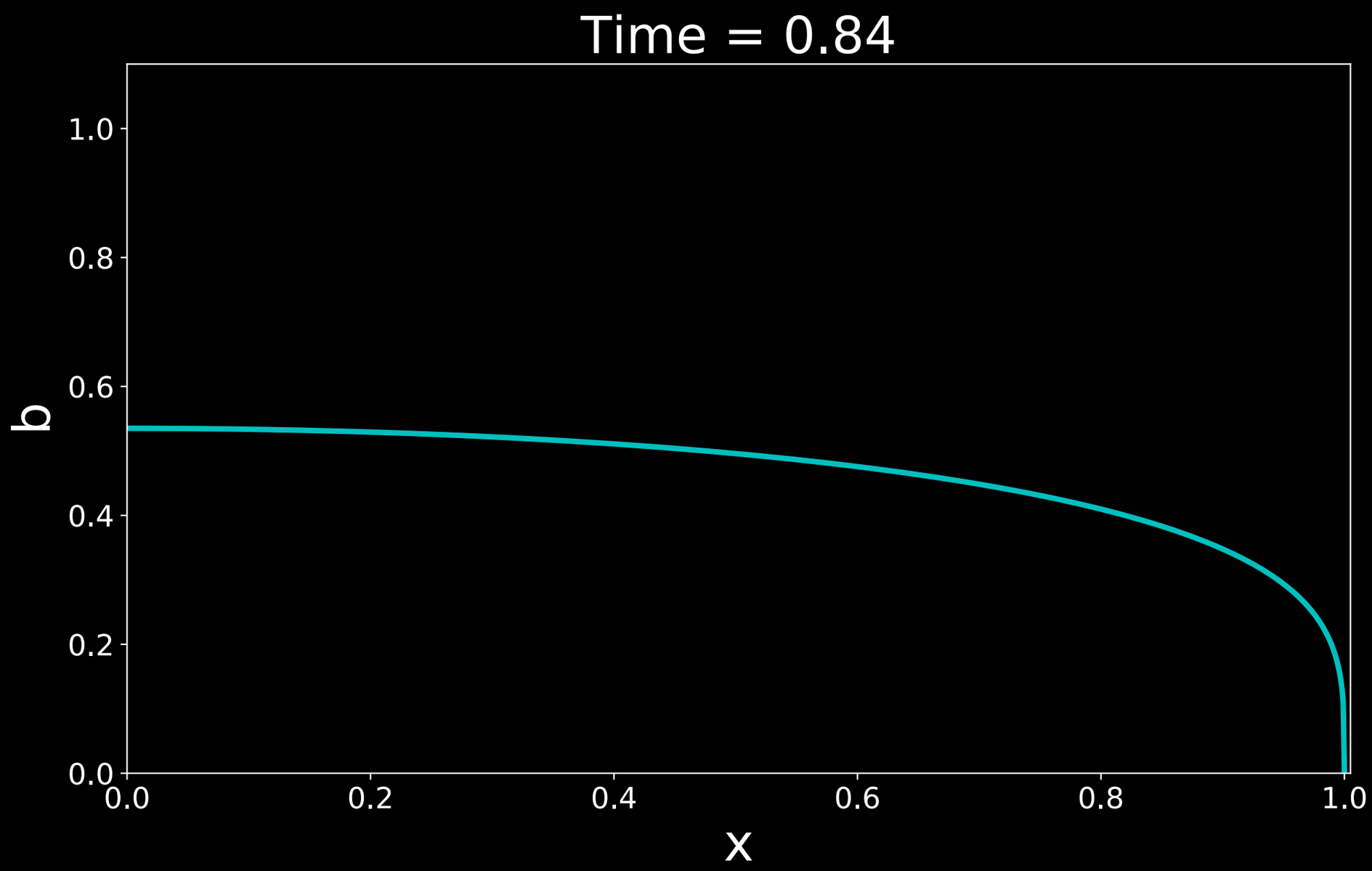


Deflating Reservoir



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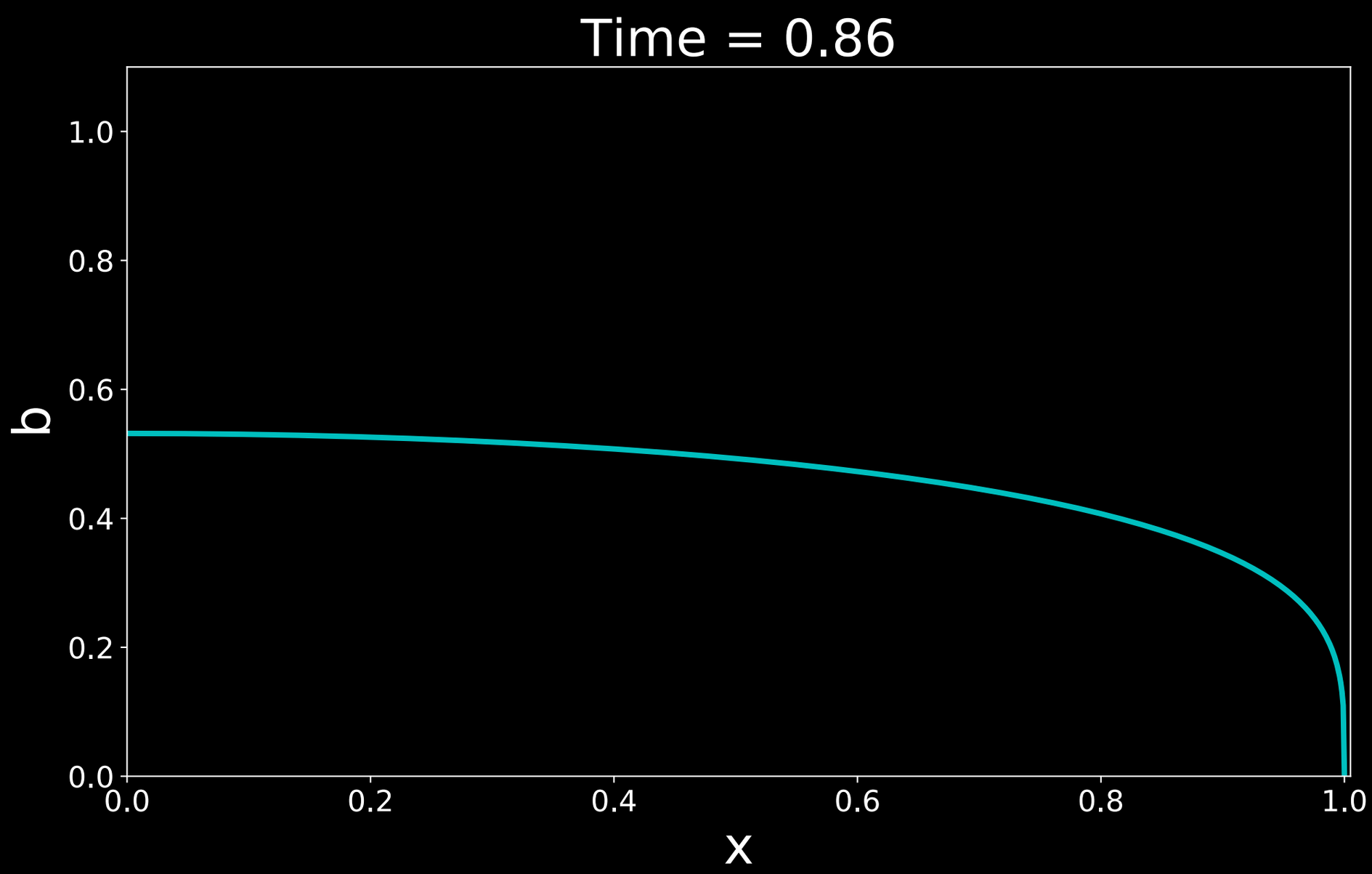

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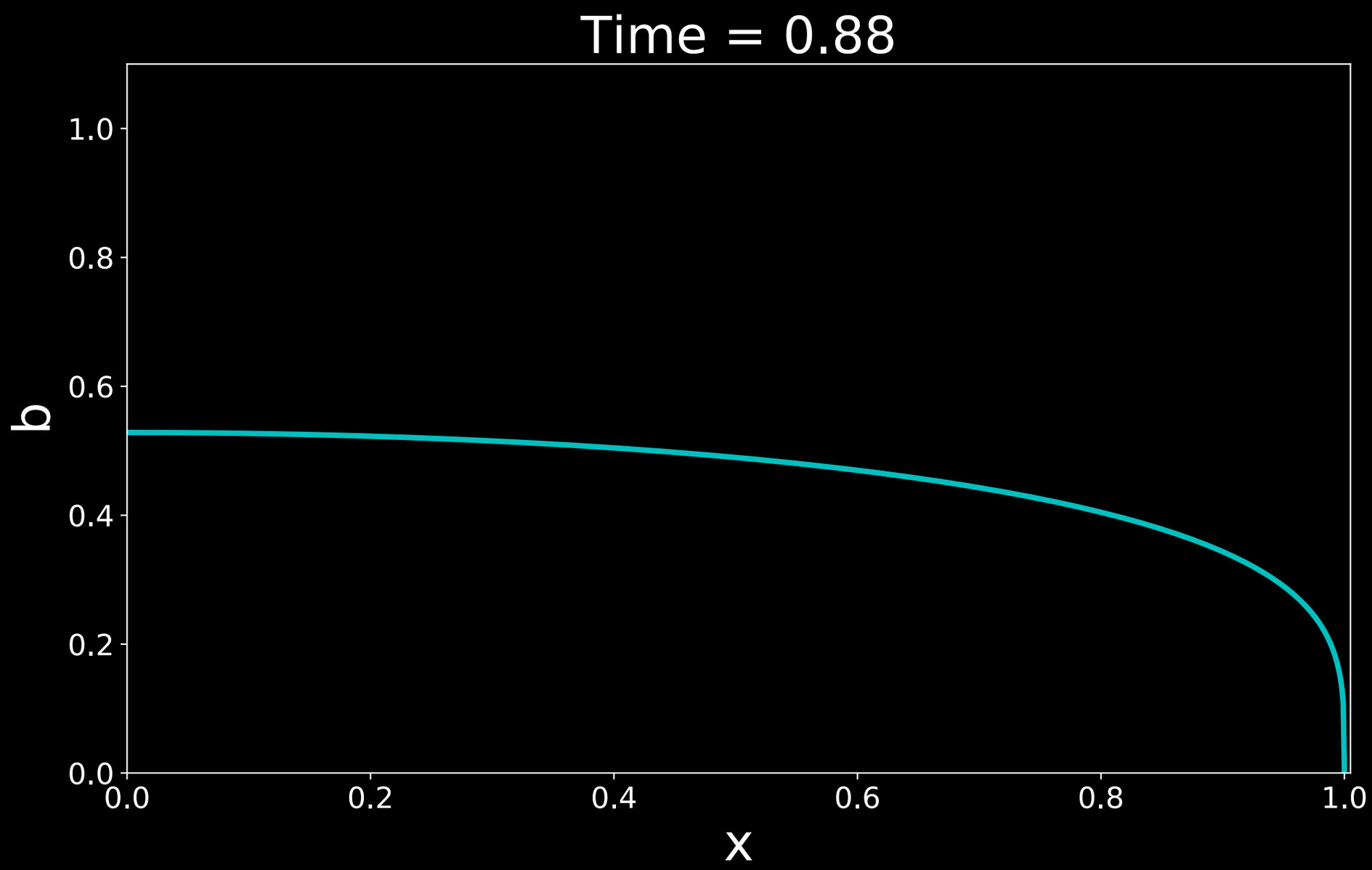

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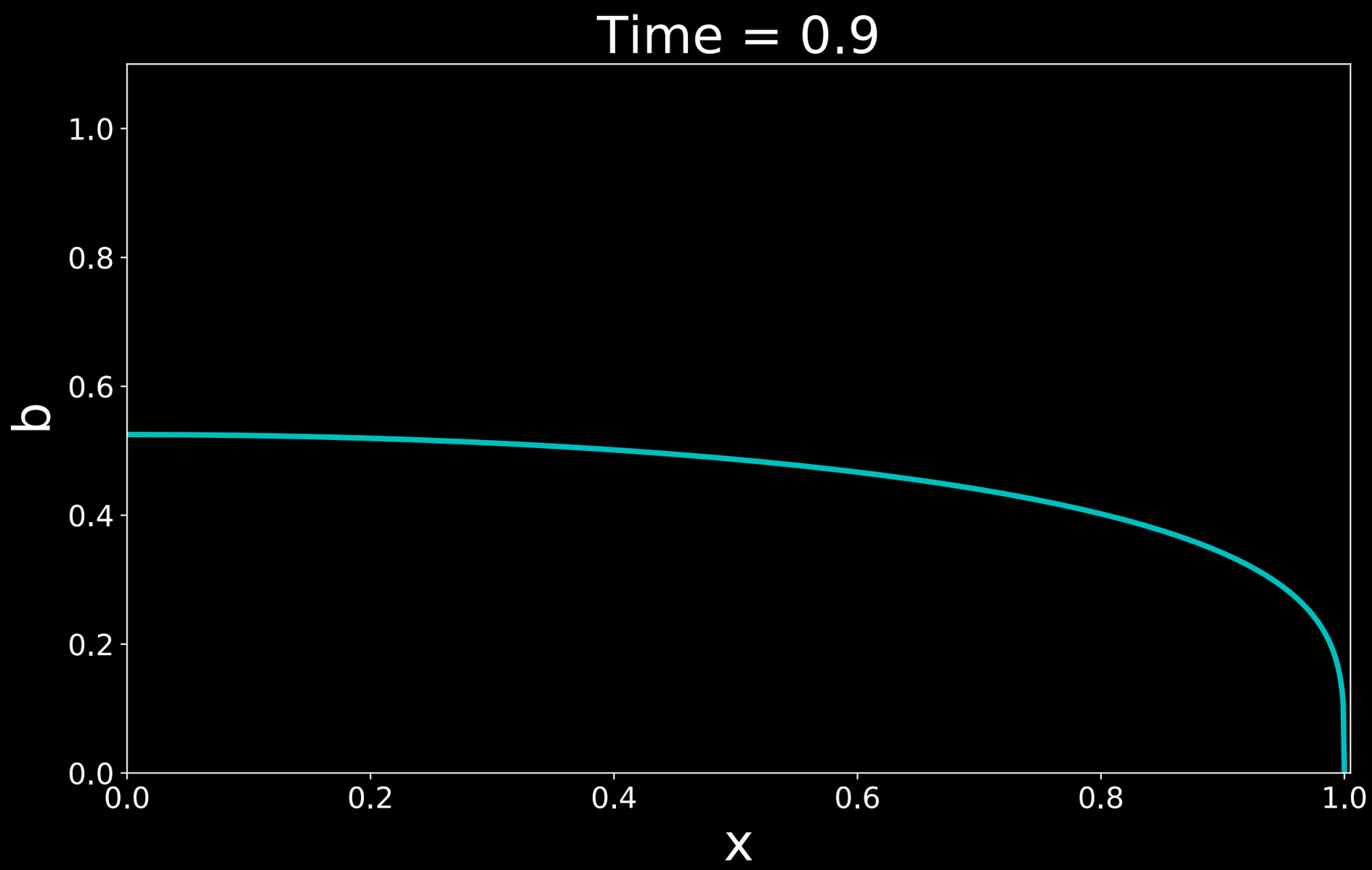

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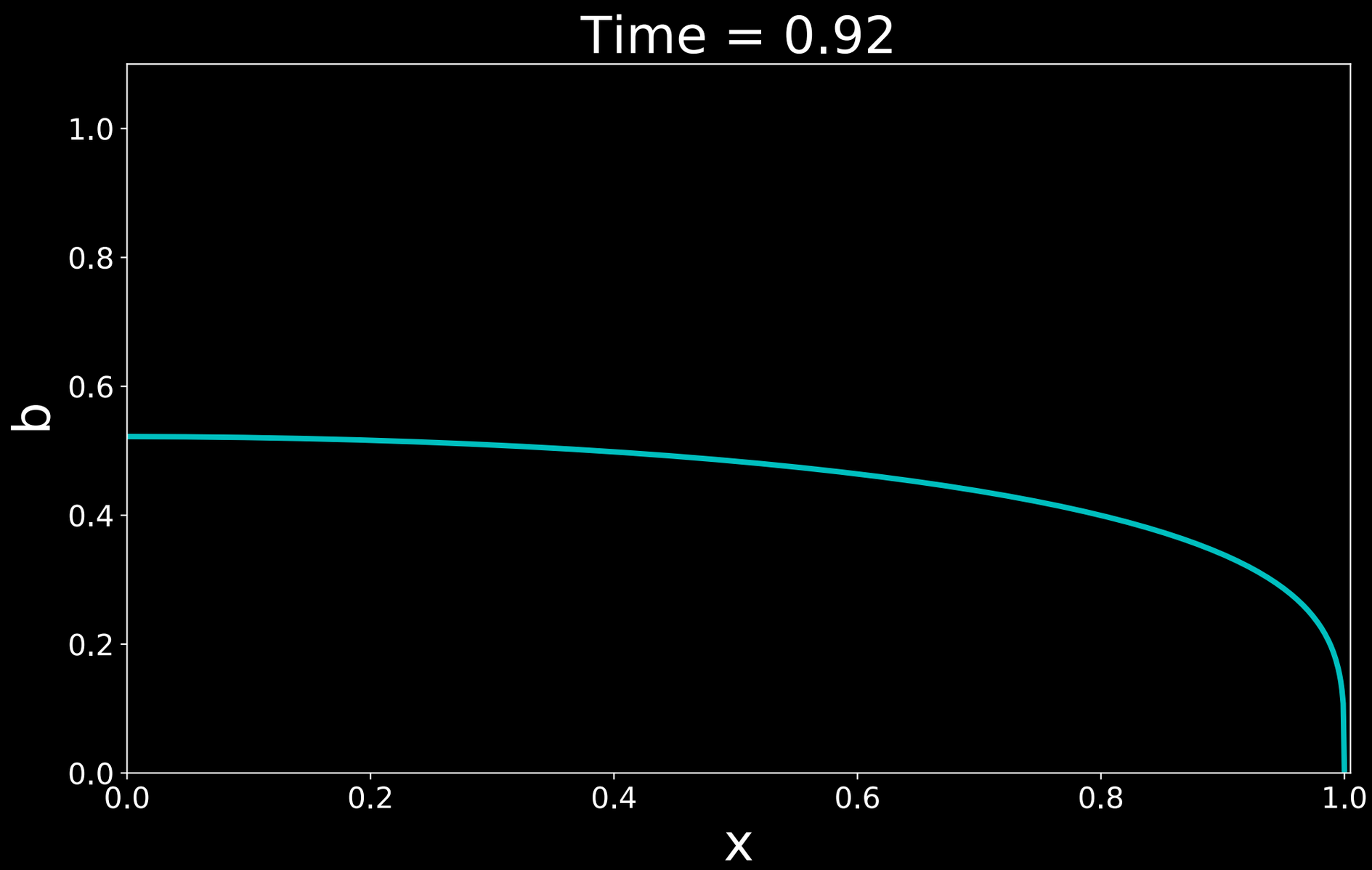

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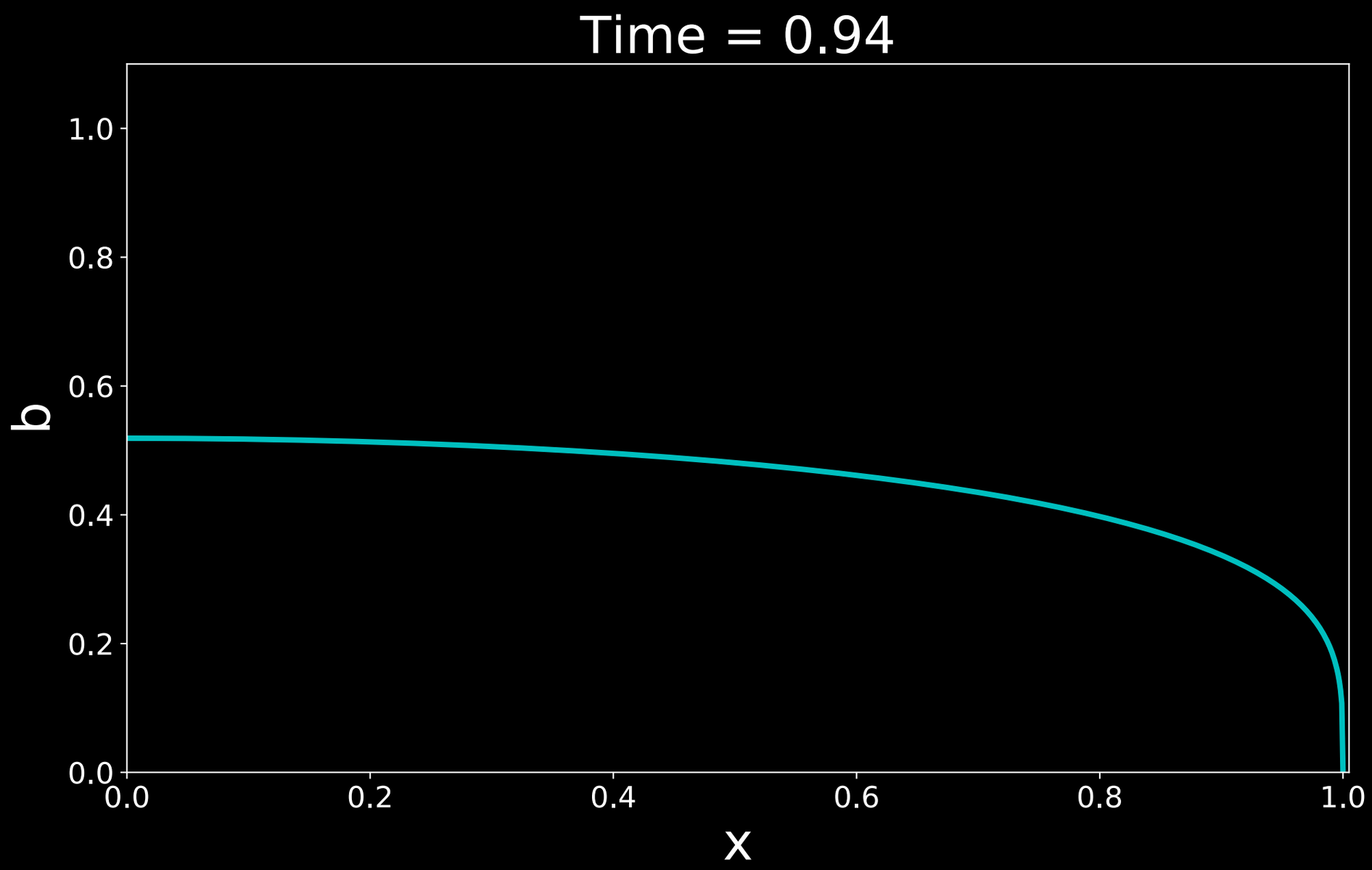

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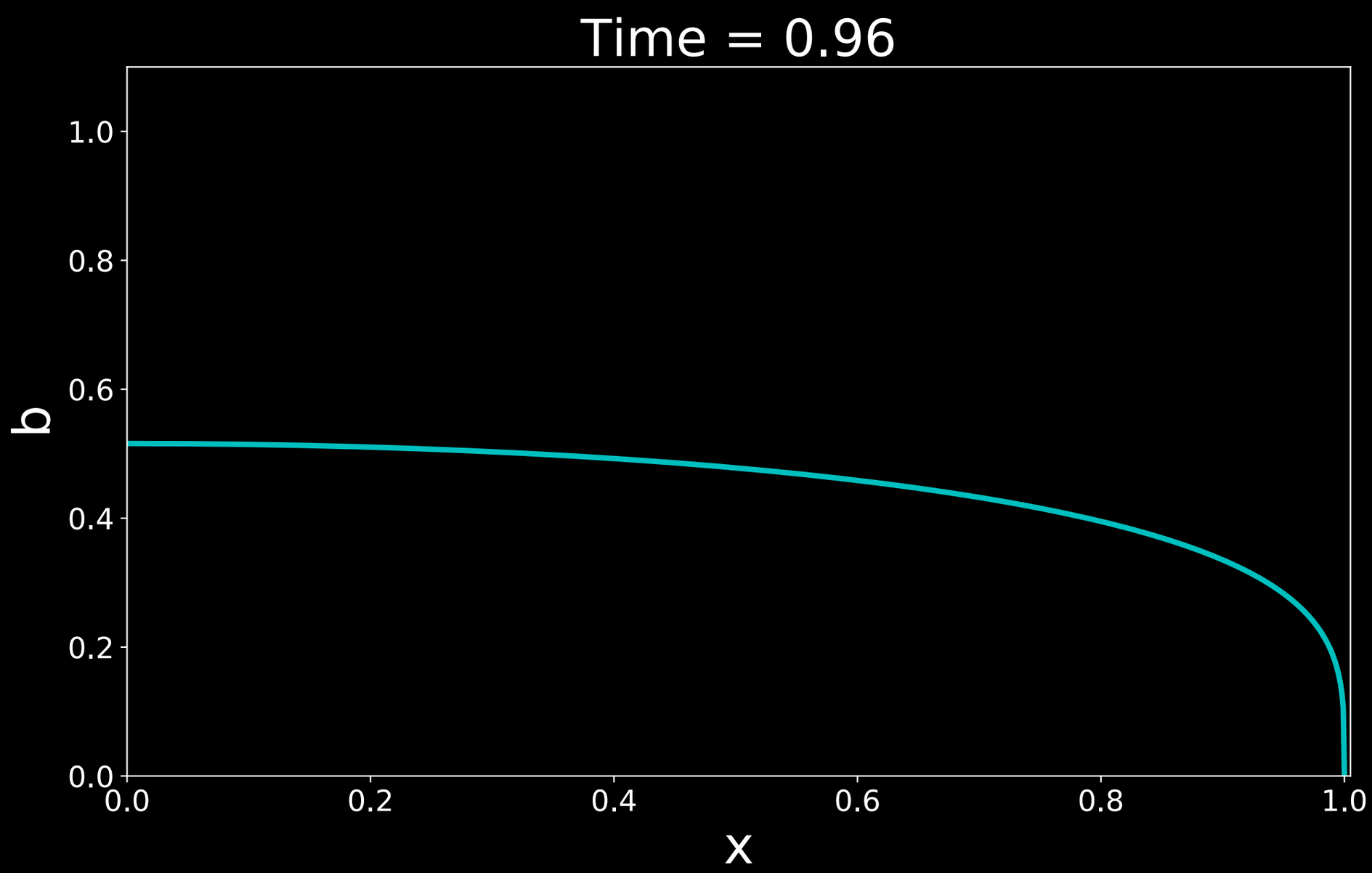

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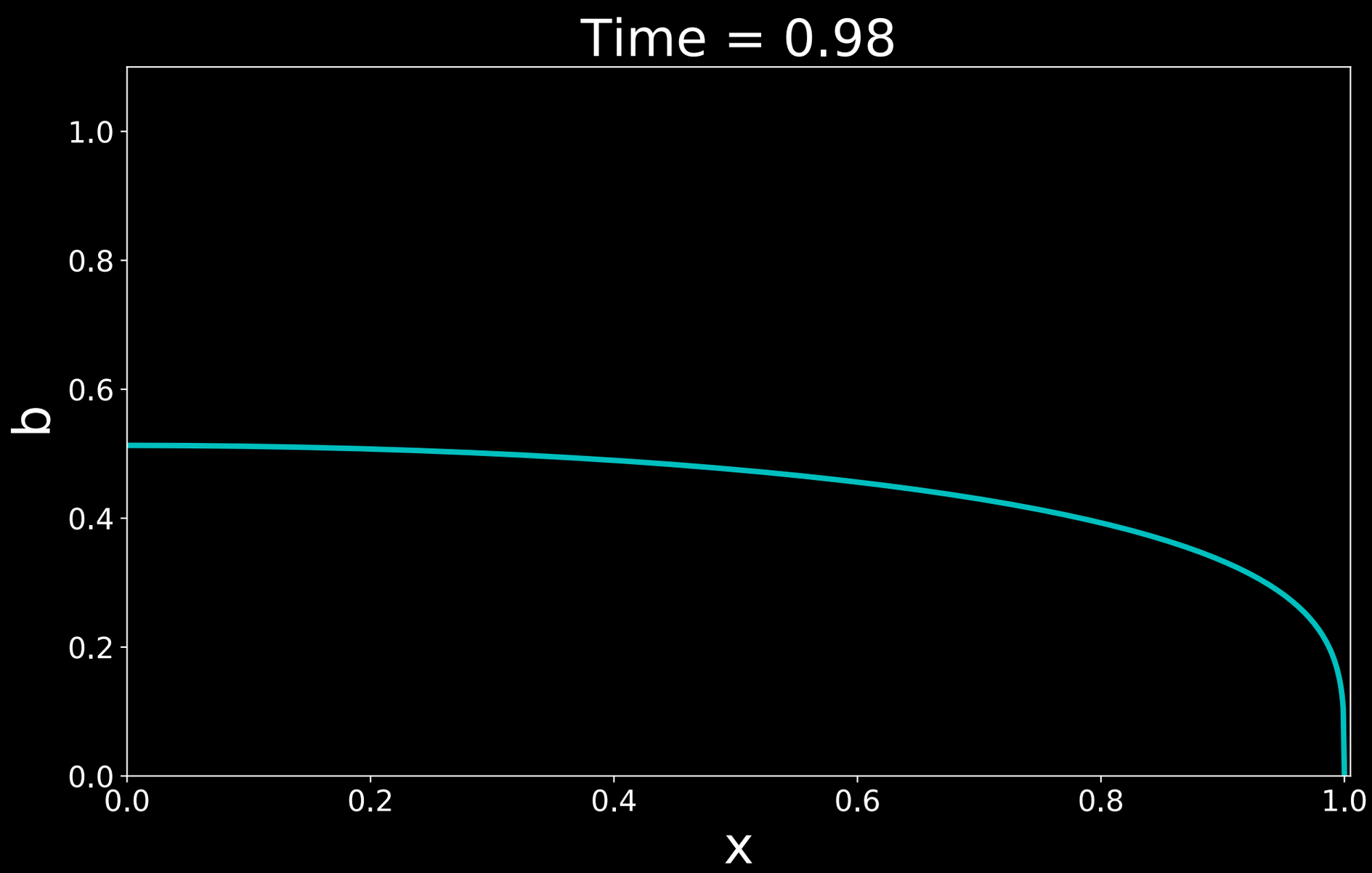

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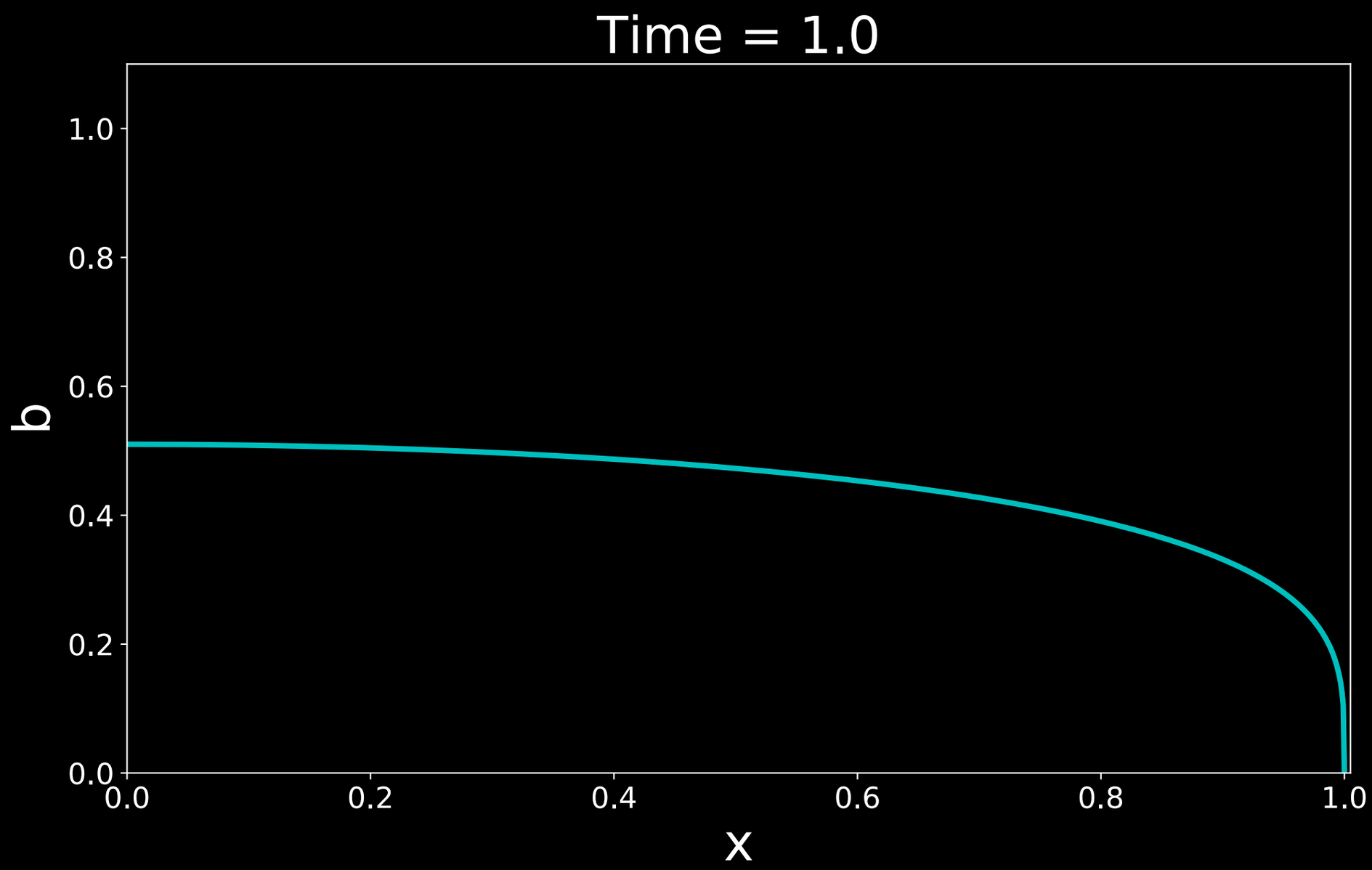
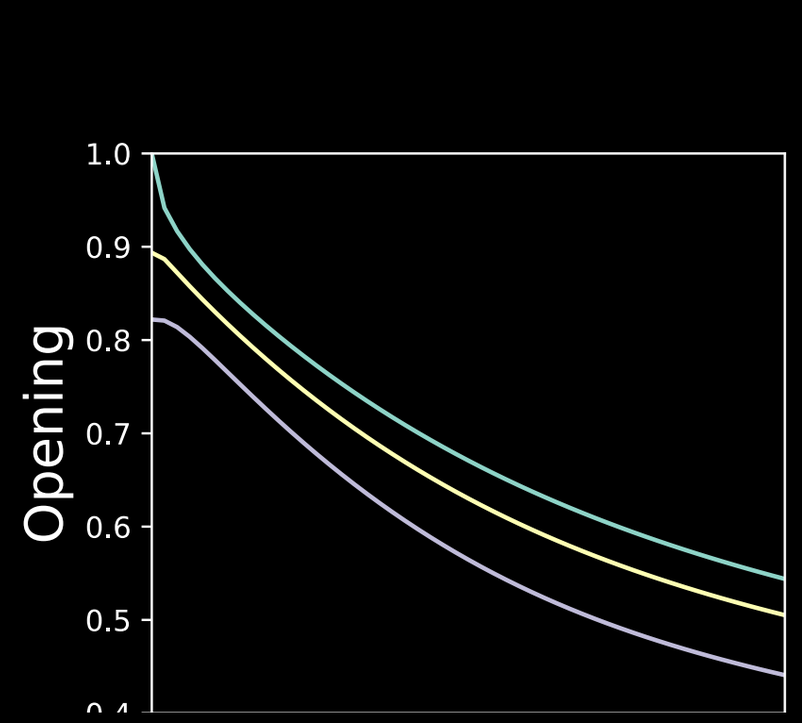
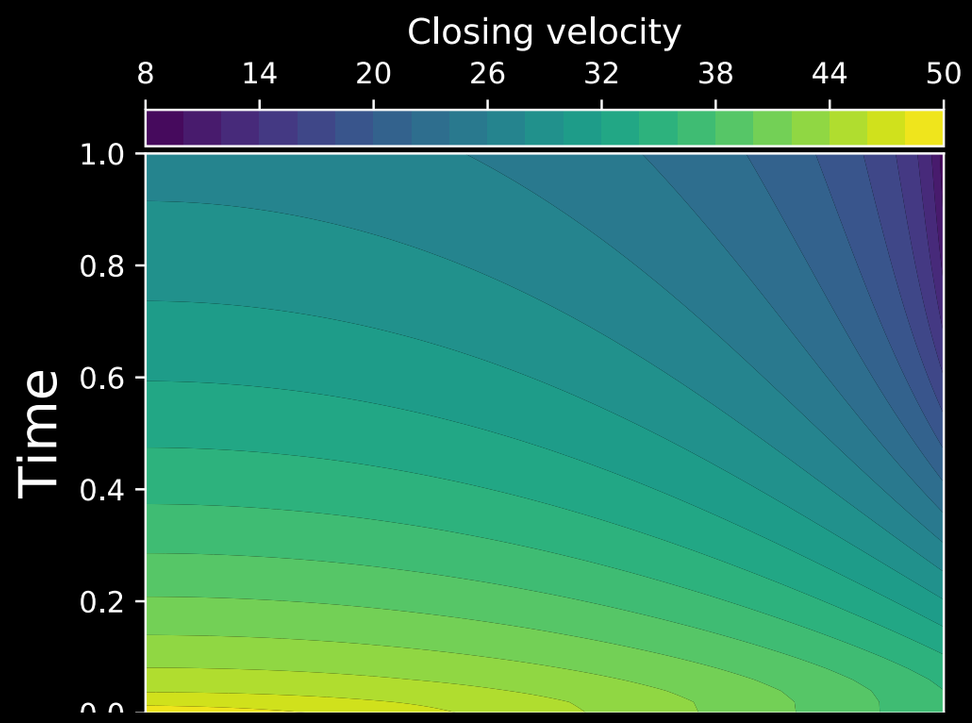
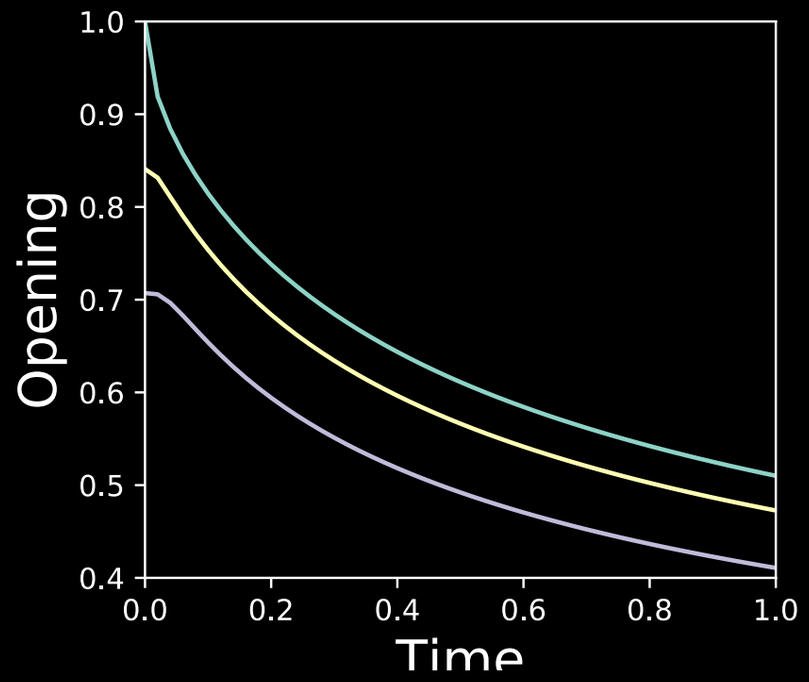
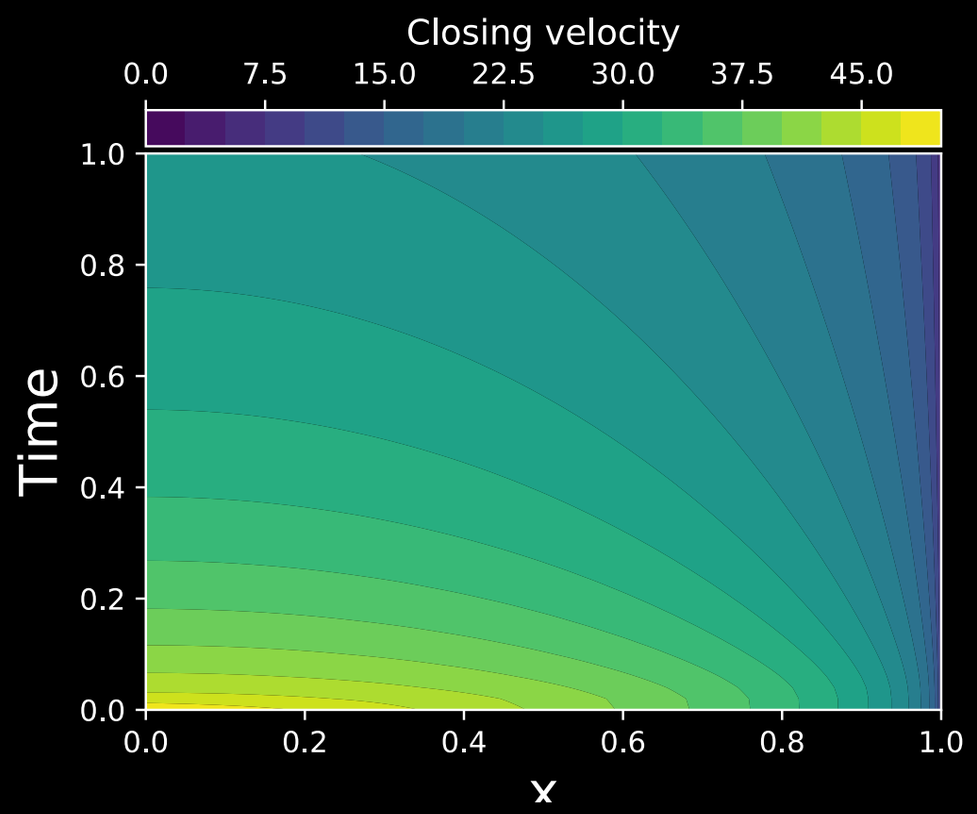


Rates of deflation

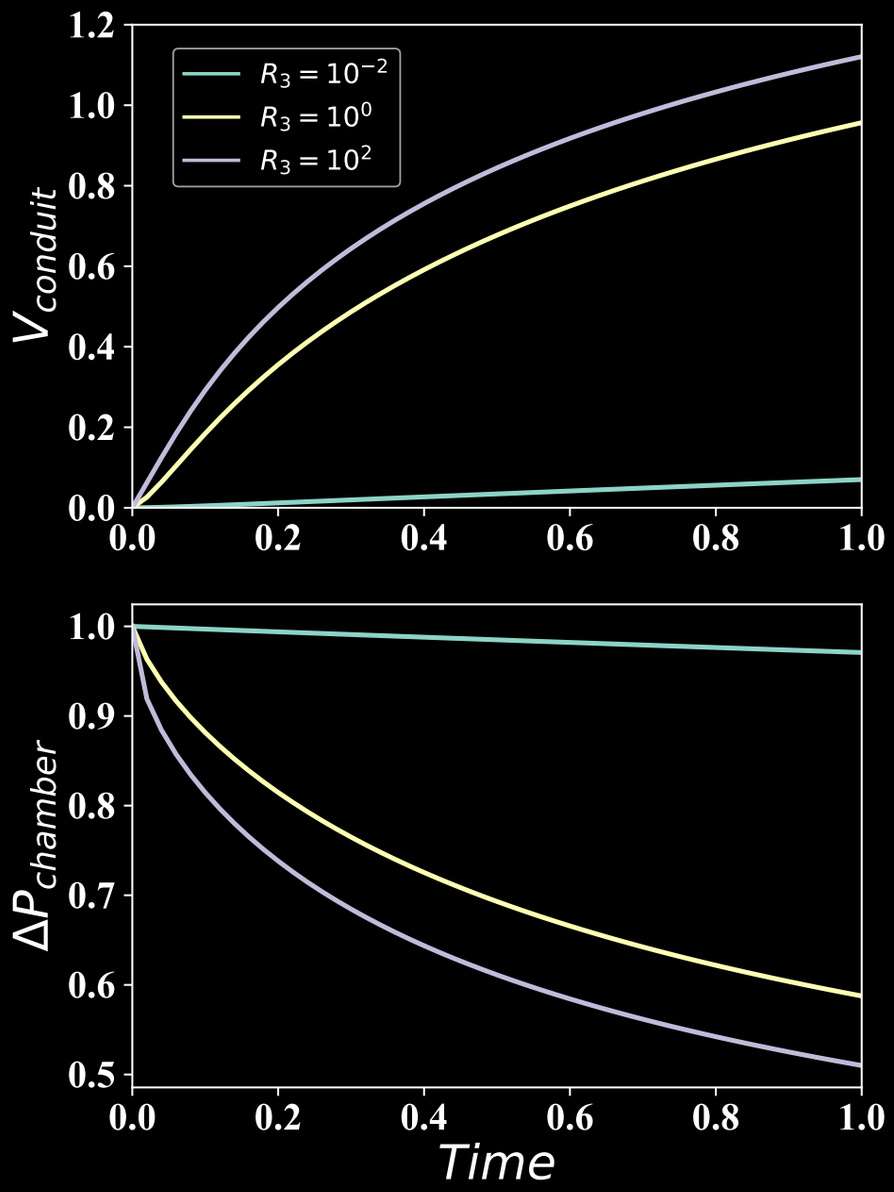


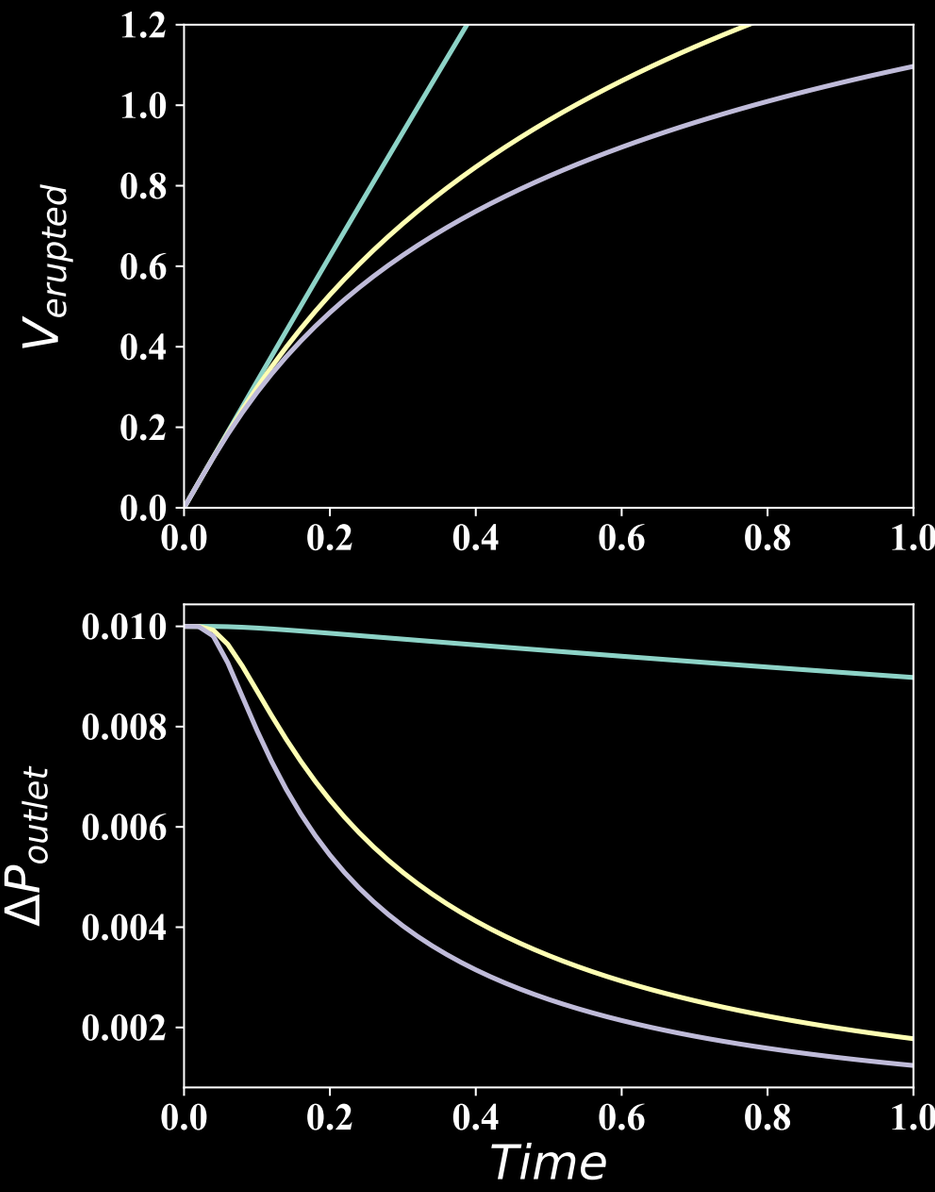






Volumes/Pressures History





At high R3 numbers volumes and pressure histories do not have a simple exponential form!

Conclusions

- Simple models of effusive volcanic eruption predicts simple exponential form for the evolution of the pressures and erupted volume
- These models neglect the link between the source overpressure and the width of the conduit
- The 2018 Sierra Negra eruption, because of the favourable geometry allow to track the evolution of the conduit feeding the eruption and show differential closing along-strike
- A simple elastic model show that the dynamics is governed by two simple dimensionless parameters quantifying the viscous pressure lost in the elastic/inelastic part of the conduit and the compressibility of the source and of the conduit
- Differential closing occur along-strike in the conduit because of the viscous pressure lost
- Non exponential forms of volumes and pressure history are predicted if R3 values are >> 1